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AN UNUSUAL OCCURRENCE OF STALACTITES AND STALAGMITES.

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INTRODUCTION.

Since few cases are on record of stalactites and stalagmites growing above ground, under normal atmospheric conditions, it occurred to the writer that a brief paper on the subject might be worth while. During the Summer and Fall of 1931 the author conducted a careful investigation of the rate and mode of growth of stalactites, and obtained some data on stalagmites.

The writer does not assume from the data obtained that one is able to arrive at a definite figure as to the length of time any large stalactite or stalagmite has been growing. As pointed out by Allison[1] and others, there are a number of factors which affect the rate of growth, and one can hardly expect to secure uniformity in results from stalactites and stalagmites growing under diverse conditions. It is interesting to note that the rate of vertical growth of the stalactites, in the early stages of development, compare closely with those of Allison,[2] in spite of the fact that those here cited grew above ground, where evaporation would be more rapid as a result of better circulation of the air, and where the Summer temperatures are higher. One would expect the stalactites of Allison to grow slower because they developed in a mine tunnel, underground, where humidity was high and the summer temperatures lower.

[1]Allison, Vernon C. The Growth of Stalagmites and Stalactites. Journal of Geology, Volume 31, 1923, pp. 106–125.

[2]Idem., p. 111.

CONDITIONS UNDER WHICH THE STALACTITES GREW.

The photograph, Fig. 1, is a view of the steel bridge of the Pennsylvania Railroad, where it crosses Bever Street in the city of Wooster, Ohio. According to railroad officials this bridge was constructed in part in 1908 and the remainder in 1912. It is approximately 200 feet long and 75 feet wide and rises about 20 feet above the paved street. Steel, lattice-work pillars support a superstructure made of thick, steel plate riveted together in an imperfect fashion to form a series of rectilinear, box-like structures, about a foot wide and about that deep. After the completion of the steel framework, concrete was poured into the boxes or troughs, filling them and covering them with several more inches, making a fairly smooth surface of the whole. On top of this steel and concrete base was laid approximately four feet of crushed limestone which was obtained from quarries located near Dunkirk and Bloomfield in northwestern Ohio. Some of this stone has a comparatively low magnesium content. Mixed with the rock ballast, but in small amount, are the usual cinders and fine coal found along railroad tracks. Due to poor drainage, much of the rain water accumulates in pools and gradually seeps into and through the rock ballast and cracks in the cement and out through the joints between the steel plates. The stalactites hang from the edges of the rectangular boxes where the joints occur, or from the steel girders just below them. More than three hundred were counted, varying from a fraction of an inch to twelve and one-half inches in length. New ones are forming at all times and most of them are in process of growth. After a heavy rain the drip is most active and least during a period of drought and during the cold winter months when the ground is frozen.

It is clear that the conditions here, above ground, are quite different than those in a cave, where the humidity is higher and summer temperatures lower. The temperature underground varies little throughout the year, whereas above ground it varies from as low as 10 degrees below zero in winter to as much as 100 degrees in summer. During this season, when the pavement is hot and automobiles are constantly passing beneath the bridge, the circulation of warm air must necessarily be favorable to rapid evaporation. Underground, stalactites and stalagmites grow all the year round, whereas above ground

in this latitude their growth must vary more or less with the seasons. The conditions are unusually favorable for rapid growth during the summer when evaporation is high, provided the rainfall is normal. Organic acids derived from decaying vegetation and the roots of growing plants are said to aid in dissolving limestone. Here, there is high concentration and no vegetation present; organic acids are therefore of no consequence in this case. The water in its downward journey through the limestone and cement picks up its load; how much is obtained from the limestone and how much from the cement is impossible to determine. The stalactites described by Allison[3] developed as a result of percolation of water through concrete. He arrives at the conclusion that carbonic-acid charged water abstracts limestone more easily from young or green concrete.

ANALYSIS OF THE STALACTITES AND STALAGMITES.

An analysis of the stalactitic and stalagmitic material was made by J. W. Ames, associate in agronomy at the Ohio Experiment Station located at Wooster, Ohio, and is as follows: Calcium Carbonate, 93.88%, Magnesium Carbonate, 1.53%. The total carbonate content is 95%. This signifies that the Calcium and Magnesium are practically all in the form of carbonates. The remaining 5% is Aluminum and small amounts of insoluble material, Silica and Iron. The solution has a bitter taste.

MODE OF GROWTH OF THE STALACTITES.

The stalactites start as slender tubes about 0.4 cm. to 0.5 cm. in diameter at the tip, widening sharply near the base to a diameter varying from 0.8 cm. to 1.5 cm. The walls vary from an extremely thin fragile shell, .2 mm. to .45 mm. in thickness to more than a quarter of an inch in the larger ones. They are all symmetrical, tapering off uniformly to the tip and showing no variations or inequalities in diameter. A great number of specimens, large and small, were measured and found to have diameters at the tip of 0.35 cm. to 0.5 cm., the average being 0.4 cm. It is the diameter of the drop, regardless of the length and diameter of the stalactite, which here controls the diameter of the tube at the tip of the growing stalactite.

[3] Idem., 1.

The writer had adequate opportunity to make a careful study of the development of stalactites in their early stages of growth. A great number of them were studied in all stages of development, from the fragile rim deposited at the periphery of the initial drops, to those twelve and one-half inches long. The manner of growth, from the first drops of solution which hang from the steel girders first commands our attention. The size of the initial drop is determined to a large extent by the nature of the surface from which it hangs. Those measured were found to vary from 0.8 cm. to 1.5 cm. in diameter. The shape and diameter of the initial drop determines the shape and diameter of the base of the initial stalactite. Observation of a number of drops suspended from a flat surface reveals a conical form. The sides curve up concavely from the rounded tip. As the drop grows in size, and becomes more elongated, the sides become more concave. When the weight of water (gravity) becomes greater than the surface tension, a drop falls. As the drop hangs from the surface, it loses water by evaporation, and carbon dioxide as a result of less pressure. Particles of calcium carbonate are precipitated and form a translucent film over the drop. This film breaks if the evaporation is good and the particles go whirling to the rim of the drop, where they become attached to the wall of the growing stalactite. This spinning motion observed in drops on actively growing stalactites is due to surface tension and to the fact, as pointed out by Allison, that the down-flowing current is at the center of the drop and the up-flowing current at the periphery. The first deposition takes place at the periphery of the initial drop, the diameter of which is much greater than the stalactite which develops later. The addition of successive zones of carbonate of lime gives the base of the stalactite a conical shape, like that of the initial drops. The writer examined a number of stalactites in their very earliest stages of growth and found that the conical base takes the shape of the initial drop. In some cases a translucent film forms over the entire drop, enclosing it in a thin delicate shell. These shells all have the shape of the drop; conical with concave sides. They serve to hold the water and have the appearance of large blisters, which when broken are found to be full of water. They are horizontally banded, indicating that their vertical growth was by the addition of calcium carbonate to the rim. An examination of the interior of the delicate, conical shells reveal horizontal

zones of minute, rounded botryoidal excrescences, a form frequently taken by calcium carbonate. These excrescences are also present inside the fragile shell, in zones or bands of growth, at the tip of the growing stalactite. When the drop is "alive" and the stalactite continues to grow, which is usually the case, the tip of the basal cone is open. The constant push of the water from above ruptures the film. The opening at the tip of the cone has the diameter of the drop which is about to fall. The diameter of the stalactite at the tip of the cone is therefore determined by the diameter of the drop at that point. As the stalactite lengthens, its diameter at the tip is constant or nearly so, because the diameter of the tube governs the diameter of the drop. It appears that the drops from all the stalactites are nearly the same diameter, measuring at their tips 0.35 cm. to 0.5 cm. in diameter, the great majority measuring 0.4 cm. This would indicate that surface tension is the controlling force which determines the diameter of the drop. The force would be equal to, or slightly exceeding the weight of the water in the drop. If the force of surface tension were constant, the size of the drop would be the same in each case. This would explain the uniform diameter of the tips of the growing stalactites.

As the stalactite lengthens, its diameter above the tip increases. Successive, concentric rings of growth are added to the exterior of the initial tube. The calcium carbonate is very porous, resembling calcareous tufa. Spaces are present between the rings of growth and openings occur in the walls. The water is held in the tube and spaces by capillarity. The pores allow the water an easy exit to the exterior of the stalactite where evaporation is responsible for additional deposition. Carbonate of lime is also deposited interstitially. In the large stalactites taken from caves, the rings of growth are present but no spaces are present between them. The tubes in the larger ones are closed by carbonate of lime. As the stalactite increases in length and diameter by additions to the exterior, its evaporating surface increases. As a result, much of the carbonate of lime is deposited interstitially and added to the exterior to increase the diameter, and a smaller proportion reaches the tip to increase its length. In this case the spongy, porous, calcareous material holds part of the solution. As a stalactite increases in diameter its vertical growth is slower.

The stalactite tubes are frequently sealed over at the tip by a film of calcium carbonate. This explains why many of them when bisected longitudinally, exhibit tubes subdivided into sections by transverse, rounded partitions, concave upward. After the end is sealed by the film, the water, not able to break it, passes through the walls or flows down the outside of the stalactite and continues to lengthen it.

RATE OF GROWTH OF THE STALACTITES.

On August 8th, 1919, the bridge was given a coat of paint, and the stalactites that had accumulated were removed. Therefore none of the stalactites are older than the above date, more than twelve years ago. It is not known definitely whether any of them started to grow immediately after the bridge was painted, but it is probable that some time elapsed before the water could make its way through the paint which doubtless filled the joints between the steel plates. Many new stalactites have been forming at all times and it is possible that all of them are less than twelve years old. Some that have been observed during the past few years are several inches long. If we assume that the largest stalactite of the group, which measures twelve and one-half inches in length, started to grow immediately after the bridge was painted, the average growth per year would be a little over one inch. If we take an average of twenty-one of the largest stalactites, varying from 8.33 cm. to 31.75 cm., averaging 18.54 cm. in length, on the assumption that they started to grow shortly after the bridge was painted, the rate of increase in length would average for all about 1.72 cm. per year. This figure does not represent the actual increase in length per year, for stalactites increase in length much faster during their early stages of growth. This is to be expected, for as the stalactite increases in size there will be a much larger evaporating surface and a part of the solution evaporates before it reaches the tip.

It was possible to get the rate of growth for this growing season because the portion of the stalactite recently added shows up as a white deposit. The older portion has been colored by dust and grime thrown up by the constant procession of automobiles during the last year. Some of the stalactites of the growing season of 1931 are at least four inches long and the variations in length of the recent additions indicate a great difference in the rate at which they increase in length.

After two months, July and August, 1931, the group of twenty-one stalactites, included in the accompanying table, were measured again to determine what increase in length had taken place. It was found that their increase in length was extremely variable, ranging from .18 cm. to 1.98 cm. Several areas of growing stalactites were removed and in twenty days new ones developed on the site of the old ones. Three of these were .32 cm. long, one .55 cm., two .63 cm., one .72 cm., one .80 cm., one .87 cm. and another 2.14 cm. On October 20,

TABLE I.

Stalactite	Length	Diameter at Base	Diameter at Tip	Rate of Drip
1.....	8.34 cm.	0.08 cm.	0.4 cm.	One drop in 2 min.
2.....	18.76 cm.	1.12 cm.	0.4 cm.	" " " 1 min., 22 sec.
3.....	14.45 cm.	1.18 cm.	0.4 cm.	" " " 15 sec.
4.....	15.95 cm.	1.04 cm.	0.4 cm.	" " " 16 min., 40 sec.
5.....	15.40 cm.	1.35 cm.	0.4 cm.	" " " 9 min., 58 sec.
6.....	17.86 cm.	0.88 cm.	0.48 cm.	" " " 6 min.
7.....	16.20 cm.	1.18 cm.	0.48 cm.	" " " 7 min., 15 sec.
8.....	16.59 cm.	0.88 cm.	0.48 cm.	" " " 9 min., 11 sec.
9.....	23.66 cm.	1.44 cm.	0.48 cm.	" " " 11 min., 30 sec.
10.....	15.24 cm.	1.5 cm.	0.48 cm.	" " " 45 sec.
11.....	20.32 cm.	1.12 cm.	0.48 cm.	" " " 1 min., 5 sec.
12.....	16.51 cm.	1.27 cm.	0.48 cm.	" " " 15 min.
13.....	15.07 cm.	1.04 cm.	0.4 cm.	" " " 24 sec.
14.....	16.12 cm.	1.27 cm.	0.48 cm.	" " " 8 min.
15.....	17.94 cm.	1.04 cm.	0.48 cm.	" " " 7 min.
16.....	17.14 cm.	1.04 cm.	0.4 cm.	" " " 7 min.
17.....	20.23 cm.	1.04 cm.	0.48 cm.	" " " 5 min., 15 sec.
18.....	20.72 cm.	0.88 cm.	0.48 cm.	" " " 10 min.
19.....	23.50 cm.	0.88 cm.	0.4 cm.	" " " 18 min., 35 sec.
20.....	31.75 cm.	1.12 cm.	0.48 cm.	" " " 30 sec.
21.....	23.64 cm.	1.27 cm.	0.48 cm.	" " " 37 sec.

1931, two months after the stalactites were removed, thirteen were measured to obtain their length. The following figures in centimeters shows their growth: 1.7, .9, 1.92, 1.87, 1.37, 1.5, 1.8, .71, 1, 1.76, 1.7, 1.77 and 1.87. The average increase in length per month is .76 cm. which compares favorably with the readings obtained by Allison[4] who reports growths varying from 0.10 cm. to 1.44 cm., averaging for all .71 cm. That the two results are so nearly alike seems remarkable, in view of the fact that the conditions under which both groups were developed are so different. One would expect those above ground to grow much faster.

[4]Idem. I, p. 111.

It was found that in general the small stalactites have a faster rate of drip than the larger ones. The average drip taken from a number of those in the early stages of development indicate about one drop in fifteen seconds. The rate for the larger ones is much less and quite variable. Allison comes to the conclusion that rapid vertical growth is favored by high air circulation, high temperature and high concentration and is opposed by rapid drip and high humidity. Large diameter, he remarks,[5] is favored by low air circulation, low temperature, high concentration and high humidity, and opposed by rapid drip. In this case the small stalactites, in their early stages of development, grow faster vertically and drip faster.

The average large stalactite here certainly does not weigh more than one-half ounce. On the assumption that the largest ones started to grow twelve years ago, shortly after the bridge was painted, it would take 3,840 years to produce one weighing 10 pounds and 38,400 years to grow one weighing one hundred pounds. These figures cannot indicate more than the fact that large stalactites are old. We are assuming that the length of time for accumulation was the maximum, twelve years, when a closer approximation would probably be less; how much less is impossible to determine.

THE GROWTH OF STALAGMITES.

The stalagmites which have grown on the steel girders and rock walls since 1919 vary considerably in length. Most of them are broadly rounded and others are narrow or of the mushroom type, varying from a fraction of an inch to two or three inches in height. One measured 2.22 cm. and another 3.1 cm. They are in some instances very porous with cavities in them which are lined with excrescences. They are made up of concentric shells or layers of growth. Some of the stalagmites are growing fast and others slowly, as indicated by their shape and width. Allison[6] observes, "A sharply convex face means a rapidly growing stalagmite and a blunt face means a slowly growing stalagmite." Several have splash cups which differ in width and depth; others have no splash cups. According to Allison, the deeper the splash cup the faster the drip, and the better the evaporation and the wider the splash cup,

[5]Idem. I, p. 113.
[6]Idem. I, p. 118.

the greater the fall. The stalagmites formed where the distance of fall was small had excellent but small splash cups, whereas those formed twenty feet below on the walk and curb are quite broad, several inches across, with gently convex surface and no splash cup.

The writer collected six stalagmites, four of which are reproduced as pen sketches. Number one is 3.33 cm., number two, 3.81 cm., number three, 4.13 cm., number four, 2.85 cm. in height. Number five, not shown in the sketch is 4.93 cm. high. Number one and two have hollow tubes running part way through them. The tube in number two is unobstructed, but the other in number one has transverse shells which divide the tube into partitions as in the stalactites. The writer is unable to offer an adequate explanation as to the origin of the tubes. All the stalagmites shown in the sketches were formed a few inches below the stalactites. It may be that solution removed enough of the interior of the stalagmite to produce the tube. Or perhaps a portion of the stalactite above broke off and fell in an upright position in the splash cup, allowing the stalagmite to grow around it. Another possible explanation; it may be that in this case, where the water fell but two or three inches, instead of spreading out as would certainly be true if it fell a great distance, the water would form a drop. Around its periphery and over its surface would form a delicate film of calcium carbonate. Drops from above would rupture this film at the top but the sides of the tube would be built up by constant addition of calcium carbonate at the periphery of the drop. In case the drip ceased sufficiently long, the film would form over the entire surface of the drop and ultimately become resistant enough to prevent its rupture by the falling drops. When this took place the growth would be by the addition of lime over the entire surface of the stalagmite. These explanations all have defects and the writer welcomes a satisfactory interpretation of the hollow tubes in the stalagmites. The stalagmites which formed on the curb and sidewalk, twenty feet below, are less than an inch thick and are broad, gently convex, almost flat on top and without splash cups. This condition, one might say, is due to the walking of pedestrians who would wear them down and prevent them from forming a narrow column. But this is not the case, because a number of typical stalgmites are forming on the curb where nothing interferes with their growth.

Stalagmite number three weighs an ounce. Assuming that it began to grow immediately after August 8, 1919, when the bridge was painted, it has taken twelve years for its accumulation. At that rate it would take one hundred and ninety years to form one weighing a pound and nineteen thousand, two hundred years to produce one weighing one hundred pounds. A closer approximation as to the rate of growth would be to take the average of a number of stalagmites. Because of the complex factors involved it is impossible to determine the rate at which stalactites and stalagmites accumulate over a long period of time. But we can say that large ones require a long period of time, not measured in hundreds but thousands of years.

CONCLUSIONS.

The rate of growth of stalactites and stalagmites is extremely variable, depending on such factors as the concentration of the solution, rate of drip and evaporation and loss of carbon dioxide from the solution. The rate of evaporation depends on the temperature, humidity and air movement. These factors, including the others mentioned, are so variable as to make it impossible to determine with any degree of certainty the age of a large stalactite or stalagmite.

The mode of development of stalactites and stalagmites, in their early stages, is well exemplified here. Furthermore the unusual conditions under which they are growing is worthy of the attention of those interested in their growth in caverns and elsewhere beneath the surface.

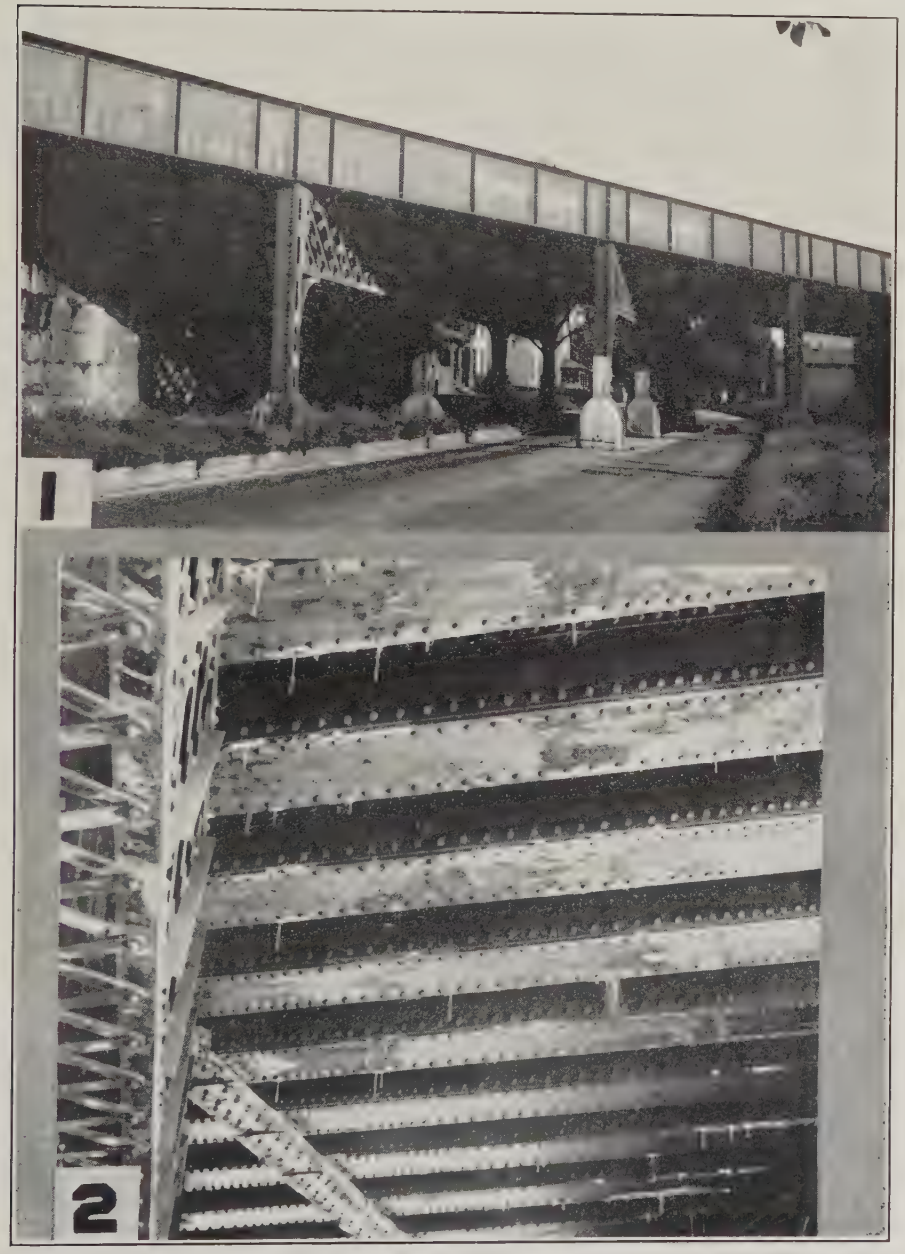

FIGURE 1. Railroad bridge crossing Bever Street, Wooster, Ohio.
FIGURE 2. A section of the bridge, showing stalactites.

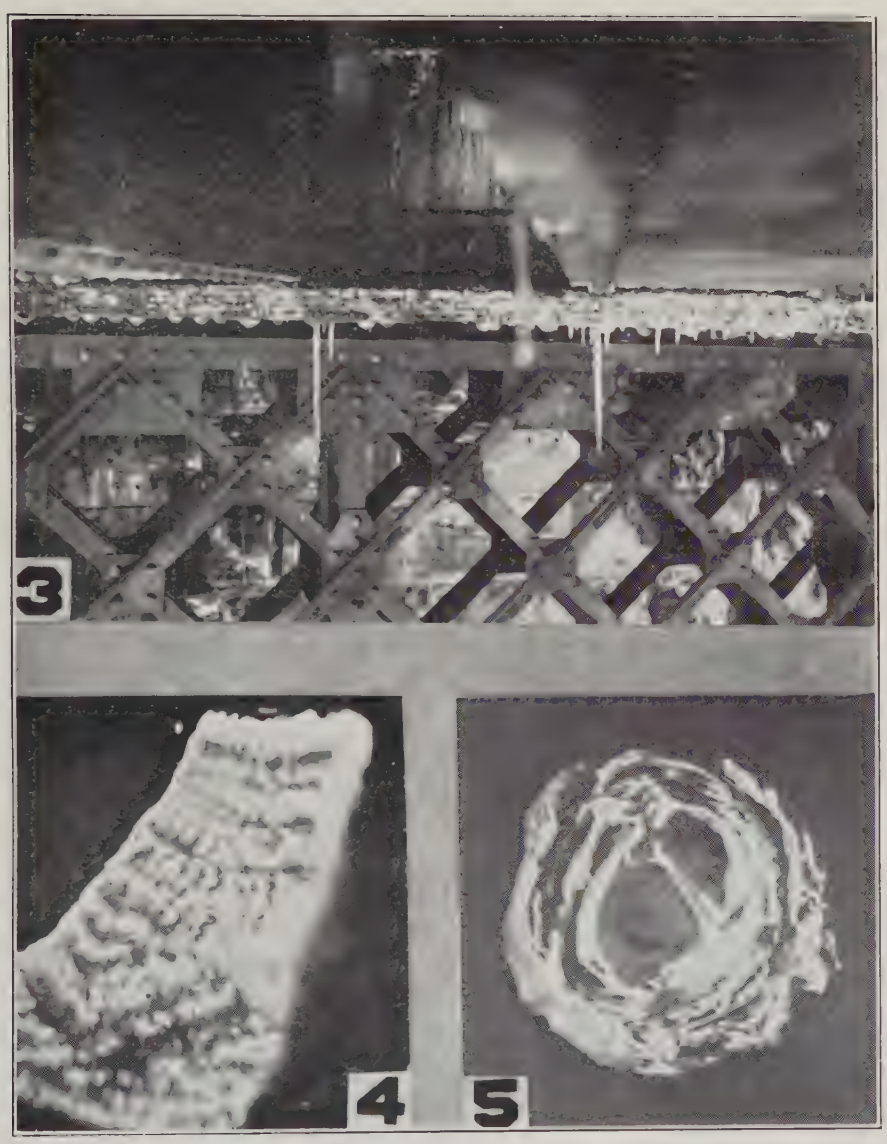

FIGURE 3. Section of the bridge showing two of the largest stalactites. The one on the left is 12½ inches long and about ½ inch in diameter.

FIGURE 4. Enlarged section of the thin shell at the tip of a growing stalactite. View of the inside, showing zones of growth. Note the rounded botryoidal excrescences, arranged in bands.

FIGURE 5. Enlarged cross-section of a stalactite, showing the tube with a transverse, concave partition. The original has a diameter of seven-sixteenths of an inch.

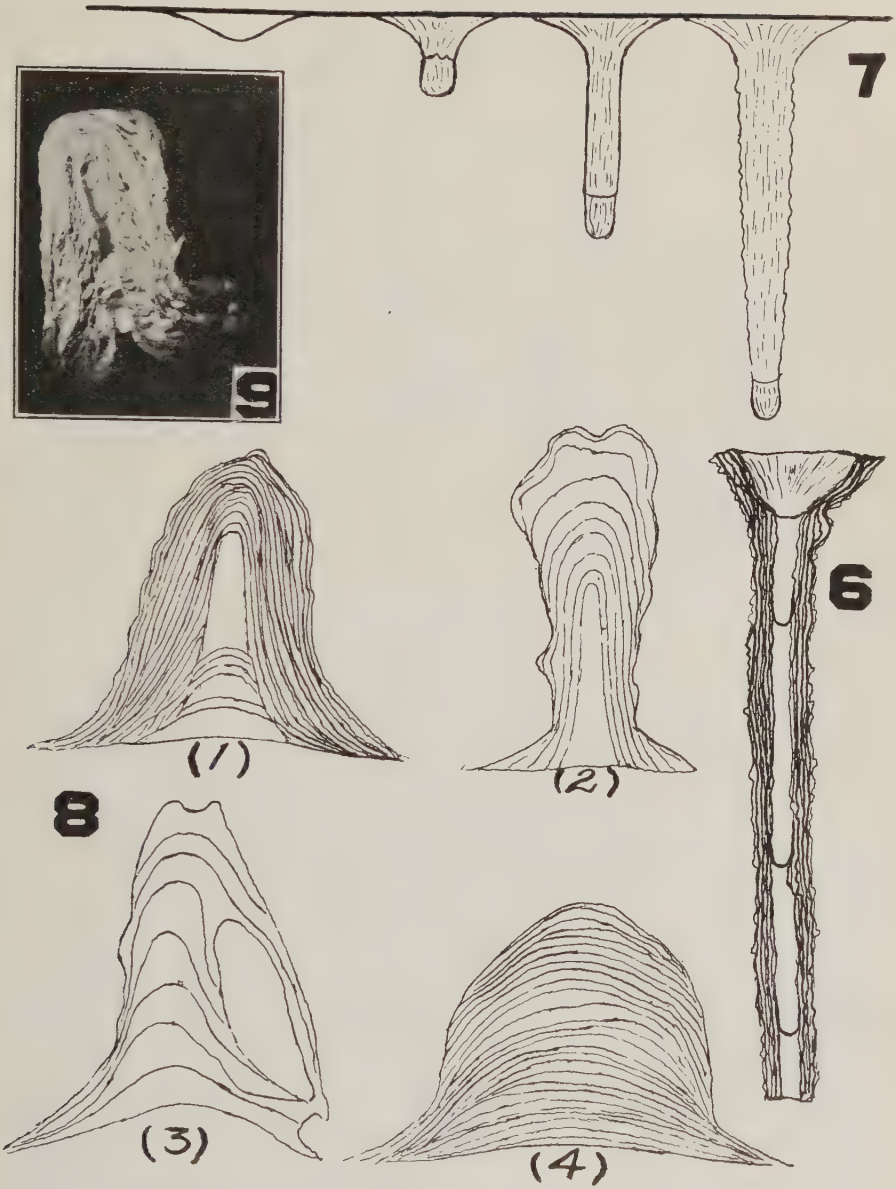

FIGURE 6. Sketch of a longitudinal section of a stalactite, showing partitions in the tube.
FIGURE 7. Stages in the growth of a stalactite.
FIGURE 8. Sketches of longitudinal sections of stalagmites. Note the tubes in 1 and 2. Numbers 2 and 3 have splash cups.
FIGURE 9. Cross-section of a stalagmite, showing tube.

LEAFHOPPER RESPONSE TO COLORED LIGHTS.

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Many persons have observed leafhoppers flying about an electric light at night and collectors, especially, have taken many species there. With the passing of the old electric arc light and the universal use of incandescent bulbs, insect attraction to light has not been so great. Almost everyone can recall the swarms of insects around an arc light. It is true that the present street lights and other lights attract insects, but without doubt much of the ultra is lost in the modern lights and hence much of their insect attractiveness.

The writer first became interested in the response of leafhoppers to colored lights in 1927 while testing the response of corn borer moths to colored lights under outdoor conditions. The apparatus was inside a screened insectary, so the leafhoppers had to pass through two screens of 12-mesh in order to reach the lights. At times the leafhoppers were so numerous that they proved a nuisance while making observations.

The 1927 data are recorded in Tables I and II. All of these data were incidental to the regular corn borer light experiments so that the set up and procedure were identical with that of the corn borer. The apparatus was set up three feet from the ground, which was the average height of the corn at the peak of moth flight.

The leafhopper apparatus for 1930 and 1931 was the same as that used for the corn borer except that all the screen was removed except from around the bulbs. The data presented below are the result of two summers' work and it is hoped that they will give additional weight to some of the writer's former work on the response of the European corn borer to colored lights.

METHODS.

The apparatus consisted of a wooden framework divided into six compartments so arranged that the leafhoppers could enter from two sides and the top. Four heights were tried

TABLE I.

Showing the Response of Leafhoppers to Colored Bulbs. 1927.

Color of Bulb	Dates and Number of Leafhoppers Responding to Lights				
	July 14	July 18	July 26	July 31	Totals
Blue	0	0	1	0	1
Green	26	82	269	17	394
Ivory	58	216	480*	67	821
Buff	18	41	34	11	104
Brown	3	95	27	14	139
Red	0	14	1	1	16
Total	105	448	812	110	1475
Temp. 9:00 P. M.	62	76	73	69	
Temp. 10:00 P. M.	62	78	70	66	
Humidity	70.5		58	45	

*The leafhoppers came so fast on July 26 that only 480 were counted, as the writer and Dr. J. P. Sleesman had to stop because they got into our eyes and mouths. There were at least 150–200 more that were not counted.

TABLE II.

Showing the Response of Leafhoppers to Colored Bulbs by Fifteen-minute Intervals. 1927.

Time	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:15	11:45	Totals
Blue	0	0	1	0	0	0	0				1
Green	8	7	11	15	17	18	14				90
Ivory	32	30	49	57	67	66	66				367
Buff	9	9	10	14	14	14	15				85
Brown	6	6	10	12	11	12	9				66
Red	2	1	1	1	1	1	2				9
Total	57	53	82	99	110	111	106				618
Blue			2	2	1		1	1	0	0	7
Green			11	18	37		36	76	82	61	321
Ivory			44	51	53		119	165	216	184	832
Buff			29	41	51		90	91	95	94	491
Brown			15	12	30		47	38	41	40	223
Red			4	6	8		12	18	14	13	75
Total			105	130	180		305	389	448	392	1,949

The data in the upper half of this chart were secured on July 31, 1927. The night was clear and cool. The temperature was 69° at 9:00 and 66° at 10:00 P. M. The humidity was 45, which was very low. The data in the lower half of the chart were taken on July 18. The temperature was 76° at 9:00 and 78° at 10:00 P. M. Unfortunately no psychrometer was available so no humidity records were taken. These readings were taken at consecutive 15- or 30-minute intervals. The light was not turned off.

for the apparatus, ground level, 1½ ft., 3 ft. and 10 ft. The 1½ and 3 ft. levels proved most satisfactory. The colored electric light bulbs were the round 25-watt type of the following colors arranged in order, red, brown, buff, ivory, green and blue. They were ordinary outside colored bulbs that can be purchased at any electrical shop. The bulbs were not corrected for intensity of wave length. The physicist at the General Electric Laboratories at Nela Park, Cleveland, Ohio, informed me that the cost of having them calibrated would be unwarranted for a cheap bulb, as it would not hold constant long enough for practical use; hence, the bulbs were used as they came from the shop.

The apparatus after being placed in various locations was permanently set up on the lawn of the laboratory. A corn field adjoined the yard and all around were maple trees with a few fruit trees, such as apple, pear, cherry and plum.

RESULTS.

The summer of 1930 presented some very interesting comparisons. There was a period when the hot, dry conditions at Oak Harbor, Ohio, were similar to those in the desert (unpublished data). Following this, 3.04 inches of rain fell during three rains from July 21 to July 26 and that constituted the rain for the season. This was followed by another hot period from July 28 to August 4, when it turned cool and remained so for the rest of the summer. During the latter part of the season heavy dews occurred.

From a study of Table III it is seen that ivory attracted 453 leafhoppers out of a total of 909. Green was second in place of attractiveness, with brown, buff and red following in the order named. This same order of attractiveness was true for the corn borer. The reason that blue, a bulb normally expected to hold an attraction for insects, did not receive any is because the color covering on the bulb does not permit the transmission of the same intensity of light as that of the other bulbs. The correlation between color of light and response of leafhoppers is .55.

The odds calculated from the formula $t = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n^1+2}$ as given by Fisher are 3,333,332 to 1 that there is a significant correlation.

TABLE III.

Showing the Response of Leafhoppers to Colored Bulbs. 1930.

Color of Bulb	Dates That Experiments Were Conducted and Number of Leafhoppers Responding																									Total
	June			July																				August		
	25	27	30	2	3	7	9	10	11	14	16	17	18	21	22	23	24	25	26	28	30	31	1	4	
Brown	9	5	1			5	3	9	11				31							11	4			36	125
Buff	8	8	3			8	6	7	13				16							20	3			31	123
Green	12	6	11			8	14	4	10				36							36	5			20	162
Red	3	0	0			1	5	6	0				9							6	4			12	46
Ivory	22	12	30			26	35	12	33				106							84	10			83	453
Blue	0	0	0			0	0	0	0				0							0	0			0	0
Total	44	31†	45			48	63	38	67				198							157	26			182	909
Temp. 8:00 P. M.	71	73	78	68	64	75	70	73	74	58	70	80	89	68	74	71	81	82	77	86	70	70	70	83	
Temp. 10:00 P. M.		69	72	58	53	66	69	72	69	52	66	73	82	72	72	67	72	75	74	83	63	64	66	77	
Average	71	71	75	63	58.5	70.5	69.5	72.5	71.5	55	68	76.5	85.5	70	73	69	76.5	78.5	75.5	84.5	66.5	67	68	80	
Humidity 8:00 P. M.	‡	46	63	83*	83*	64	67	66	74	83*	70	56	37	‡	‡	83*	‡	‡		56	84	83*	75	82	
Humidity 10:00 P. M.	†	72	‡	83*	83*	‡		69	90	83*	90	‡	41	‡	‡	83*	‡	‡		75	84*	83*	67	77	
Average	‡	59	63	‡	‡	64	67	67.5	82	‡	80	56	39	‡	‡	‡	‡	‡		65.5	‡	‡	71	79.5	
Average wind velocity, 8–10	1.1	5.2	2.8	4.0	1.2	*none*	.9	2.1	1.2	2.4	2.8	2.8	*none*	3.1	1.8	.9	.6	.6	.6	.6	*none*	1 0		*none*	
Rain								.05						.96	.38				2.70						

†Quit at 9:00 P. M., when wind increased.
*Humidity was too high at the beginning of the experiment.
‡Hygrothermograph registered above 90 percent.

Referring again to Table III, the odds according to Fisher's formula $t = \frac{\bar{x} - \bar{x}_1}{s} \sqrt{\frac{(n_1+1)(n_2+1)}{n^1+n^2+2}}$ that the differences between the colored lights are significant is shown by the following:

The odds are 121 to 1 that there is a significant difference between ivory and green, but the difference is not great enough to show significant odds for green light compared with brown. The same is true for brown and buff, two colored bulbs which are very much alike, but the odds are 92.2 to 1 that buff is more attractive than red.

Ordinary 25-watt clear glass, mill type electric light bulbs attract leafhoppers but not as much as a 100-watt Mazda C. No leafhoppers were collected from these bulbs, but counts were made. The results are tabulated in Table IV. In no case did the clear glass bulb attract as many as the ivory. On two occasions the 50-watt clear glass bulb attracted more than the green light.

TABLE IV.

SHOWING THE COMPARISON BETWEEN CLEAR GLASS BULBS AND COLORED BULBS.*

DATE	BROWN	BUFF	GREEN	RED	IVORY	BLUE	25 WATT CLEAR	50 WATT CLEAR	TOTAL
June 30	1	3	11	0	30	0	2	8	55
July 7	5	8	8	1	26	0	5	11	64
July 9	3	6	14	5	35	0	8	18	89
July 10	9	7	4	6	12	0	2	3	43
July 11	11	13	10	0	33	0	2	8	77

*Counted but not collected.

It was repeatedly observed on nights that were not good for conducting the tests that leafhoppers came to windows through which the light from a 40-watt Mazda inside frosted bulb was shining. The leafhoppers were collected but in no instance did more come the same night. It is possible that when the lights were turned on in the room, the reflection through the window attracted those in proximity and they all came within a short period of time. The fact that once they were collected no more came to the window seems to confirm the above statement.

Table V shows the name and number of leafhoppers collected at each light. The determinations were made by Prof. Herbert Osborn.

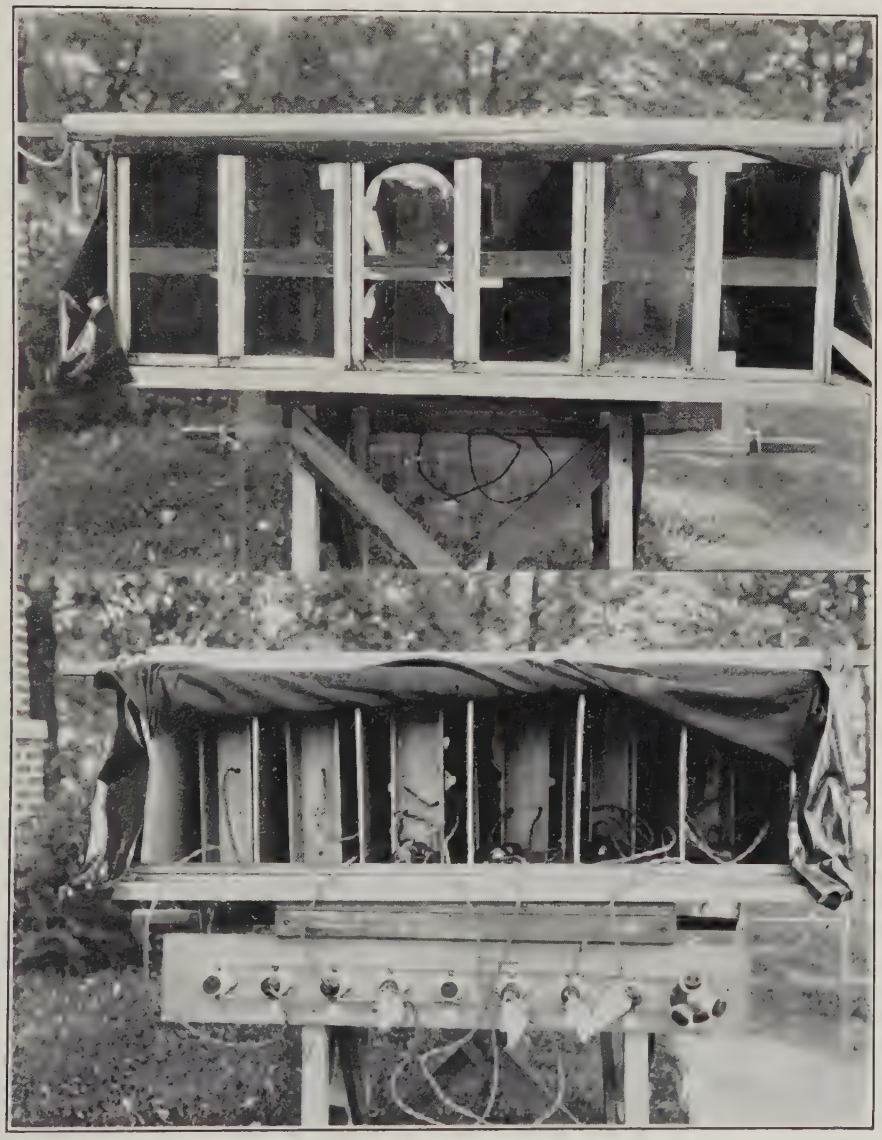
Due to the small numbers, no correlation can be made between species and color of light. From a study of the table, the first four species had the same relative attractiveness to the lights with no significant differences.

TABLE V.

SHOWING THE NAME OF LEAFHOPPERS WITH NUMBER COLLECTED AT THE COLORED BULBS. 1930.

NAME OF LEAFHOPPER	IVORY	GREEN	BROWN	BUFF	RED	TOTAL
Phlepsius irroratus	117	60	50	48	14	289
Deltocephalus inimicus	106	27	15	19	11	178
Cicadula 6-notata	80	46	9	7	6	148
Empoasca fabae	29	3	0	2	1	35
Thamnotettix nigrifrons	9	0	0	3	0	12
Scaphoideus immistus	6	0	1	0	1	8
Dikraneura fieberi	7	0	0	0	0	7
Xestpcephalus pulicarius	4	1	0	0	0	5
Gypona octolineata	0	2	1	0	0	3
Chlorotettix galbanata	1	2	0	0	0	3
Eutettix seminudus	0	0	0	2	0	2
Thamnotettix clitellarius	1	0	0	0	1	2
Dikeanura sp.	0	2	0	0	0	2
Draeculacephala inscripta	0	0	2	0	0	2
Draeculacephala mollipes	2	0	0	0	0	2
Idiocerus pallidus	0	0	0	1	0	1
Idiocerus suturalis	1	0	0	0	0	1
Gypona pectoralis	0	0	0	1	0	1
Totals	363	143	78	83	34	701

In 1931, in addition to the experiments with colored bulbs, the leafhoppers were also exposed to different wave lengths of light. The field apparatus consisted of a box framework which held six ray filters in their respective tin frames. The filters were 6½-inch squares manufactured by the Corning Glass Company. The colors and numbers of the filters were as follows: Red purple ultra, G586A; light blue green, G584J; signal purple, G55A; blue purple ultra, G585L; Pyrex and heat absorbing, G124J. The general set-up of the apparatus may be seen from the photographs (Plate I).



METHODS.

The light apparatus was set in a back yard with the following existing conditions: The lawn was mowed in front and back of the apparatus. On one side was a blackberry patch and garden while on the other, a grape arbor and garden. To the extreme front was another blackberry patch and garden, while the trees surrounding the area were soft maple, hickory, apple, pear and cherry.

Quantitative leafhopper counts were made at 15-minute intervals instead of mass collecting. The lights were turned on for 15 minutes and after the reading was taken they were turned off for the same period. In this manner a quantitative sample was taken and the period of flight determined.

RESULTS.

The season of 1931, although very well adapted for corn borer work, was not so good for night collecting. In 1930 there was a total of 3.09 inches of rain from June 25 to August 4 and 3.05 inches for the same period in 1931. However, in 1930, 3.04 inches of this rain came in three rains between July 21 and July 26, constituting the rainfall for the summer of 1930. In 1931 the same amount of rainfall was spread over the whole period. Although anemometer readings were not taken during 1931 there was noticeably more wind than in 1930.

A total of 5.59 inches of rain fell during the period from August 4 to September 16. The whole summer of 1931 was characterized by nights with heavy dew.

The 1931 colored bulb light experiments agree with those of 1930. See Table VI. There was not sufficient data for the 1931 tests with ray filters to draw any conclusions. However, from the results obtained pale blue green attracted 32 leafhoppers while pyrex was second with 25. The attractiveness of the other lights was as follows: Signal purple 23, purple ultra 16, heat absorbing 12, and red purple ultra 4. Of all the lights red purple ultra transmits the most ultra and attracts less leafhoppers. Pale blue green is the only filter not extending into the red end. Pyrex is a neutral glass and allows all rays to go through; so it is to be expected that the red end will offset the blue end. Signal purple and blue purple ultra transmit a band of red. Heat absorbing has a wide range and transmits rays of red as well as blue.

Leafhoppers responded to lights so long as the humidity

remained under 83 percent, but when the humidity increased above that point they ceased coming to the light. However, those already at the lights remained there. So far, the hiding places of the leafhopper at night have not been found.

A high temperature and low humidity are best suited for leafhopper response to light, but a high humidity, so long as it does not pass 83 percent, draws many leafhoppers. Referring to Table III it will be noted that nights having a high humidity did not attract leafhoppers. A combination of low temperature and high humidity is inimical to leafhopper attraction.

TABLE VI.

Showing the Response of Leafhoppers to Colored Bulbs. 1930.

Color	Number of Leafhoppers Taken							Total
	June 25	July 8	July 10	July 13	July 27	July 28	July 30	
Red	10	4	1	6	0	3	4	28
Buff	27	5	5	8	1	4	10	60
Brown	33	3	6	8	0	6	10	66
Ivory	48	20	10	36	4	11	33	162
Green	19	8	7	23	1	7	21	86
Total	137	40	29	81	6	31	78	402
Temp. 8:00 P. M.	82	83	75	73	72	82	88	
Temp. 10:00 P. M.	78	78	71	71	71	81	84	
Average	80	80.5	73	72	71.5	81.5	86	
Humidity 8:00 P. M.	76	80	88	73	82	68	60	
Humidity 10:00 P. M.	80	70	78	79	82	69	76	
Average	78	75	83	76	82	68.5	68	

Wind direction is important, but wind velocity is much more so. The apparatus was so designed to face the prevailing wind. Leafhoppers do not respond on nights when velocity is over 3½ miles per hour.

Catalepsy has not been observed in the leafhopper. Another interesting thing observed was that if conditions were favorable for a good leafhopper night, the insects would come to the lights despite the fact that the operator or others might be in the immediate vicinity.

Entomologists have reported occasional flights of leafhoppers at night. This habit of night flight is not restricted to any one species but represents a number of genera. No migration or exceptionally heavy flight was noticed such as occurred in 1927.

THE OCCURRENCE OF COAL AND MICA IN PLEISTOCENE DEPOSITS NEAR CINCINNATI.

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INTRODUCTION.

The occurrence of coal and mica in Pleistocene deposits has not been reported in southwestern Ohio. It may have some interest for two reasons. Because there is neither coal nor mica in southwestern Ohio, their occurrence in a deposit of transported material raises the question of their source of supply. In addition, the location of the deposit is such as to shed light on a problem of pre-glacial drainage.

LOCATION AND DESCRIPTION OF DEPOSIT.

One mile east of the point where the Little Miami river joins the Ohio river (Fig. 1, a) is a bluff cut into a deposit of fine sand covered with bowlder clay. The Miami river flows at this point southeastward in the abandoned valley of the pre-glacial Ohio, which flowed in the opposite direction. The old valley continues along the Miami, reversed in direction, about four miles and then curves northwestward through Norwood, northward through Lockland, and thence toward Hamilton, Ohio. (Fig. 1, b).

In 1929, this bluff was excavated for road-building purposes, and in such a fresh exposure the precise nature of the material was revealed.

The top of the exposure is about 615′ A. T., the base about 500′ A. T., a little above the flood plain of the river, which is here about 480′ A. T. Everything in the bluff below 575′ A. T. is sand, grading toward the top into very fine grains and very regularly laminated beds. (Fig. 2.) The upper half of the sand shows horizontal beds an inch or less apart with fine cross-bedding planes between, caused by gentle current action. (Fig. 3.)

At about 535′ A. T., the sand is cemented in place, perhaps due to the later spread of Wisconsin outwash waters through

the sand already then flanking the valley. At least the level corresponds with that of the Wisconsin water-laid terrace at Cincinnati.

Above 575′ A. T. the deposit is capped with bowlder clay, separated from the sand below by a band of limonitic cement with 10 to 12 inches of fine, laminated clay above it.

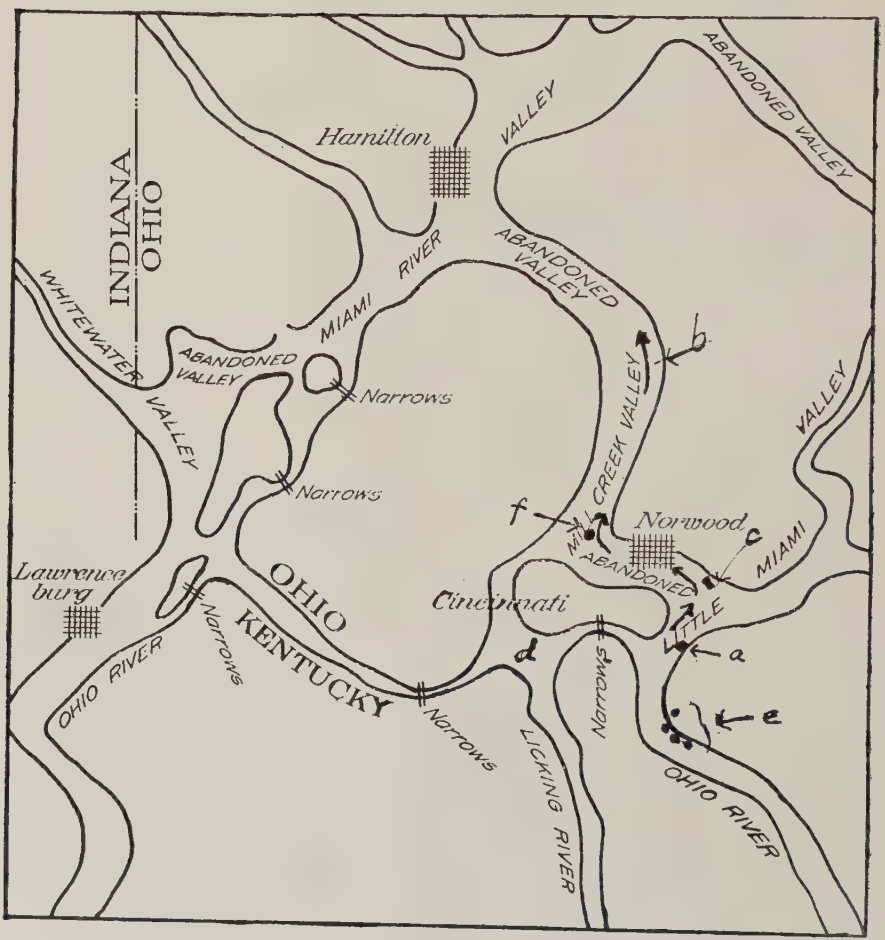

FIGURE 1. Sketch map of valleys in the vicinity of Cincinnati. (After Fenneman.)

a. Deposit with abundance of coal and mica.
b. Pre-Illinoian valley of the Ohio.
c. Gravel at surface in Illinoian valley fill.
d. Cincinnati basin.
e. Glacial outwash capped with bowlder clay.
f. Coal and mica in "Norwood trough."

An interesting fold in the beds of sand, quite distinct from the cross-bedding and on a much larger scale was exposed in 1929. (Fig. 4.) Mention of it might be omitted from the description, because it has no apparent bearing on the origin of the deposit nor on the history of the drainage. However, it was an unusual feature, perhaps worthy of mention.

The fold was about two yards long and two feet high and was cut by the excavation in longitudinal section which was at approximately a right angle to the direction of the valley. The pressure must have been due to ice shove at a time when the water at this level was frozen over. The bedding planes were perfectly preserved across the fold. This may have been due to slight cementation of lime, in case a water level had been maintained for a more or less prolonged period, or, more probably to the cementation of ice at the time of folding.

ILLINOIAN TERRACE AT CINCINNATI.

The unconsolidated material of the deposit near the Miami has been considered a part of the glacial terrace of Illinoian age, represented by remnants in most pre-glacial valleys in the immediate vicinity of Cincinnati. This Illinoian valley fill is chiefly outwash, being built up of water-laid material, often gravelly, to the level of 575′ to 590′ A. T. and capped with bowlder clay to the level of 600′ to 625′ A. T., the latter deposited as the ice overrode its own outwash.

Exceptions to this rule are to be noted where, in restricted areas in the normal valley fill, there are exposures showing gravel at the top instead of bowlder clay. Such an exception occurs in part of Madisonville and part of the new town of Mariemont on the eastern side of the "Norwood trough," the abandoned valley of the ancestral Ohio. (Fig. 1, c). This gravel is at the top at the same level and side by side with the normal bowlder clay capping and may be interpreted to mark the course of a small stream on the ice.

There are also exceptions to the general condition of outwash and no bowlder clay in the lower part. In several exposures some bowlder clay appears in the outwash, but the many exposures in which the lower part is all outwash material would seem to rule out the possibility of any general advance of the ice earlier than the last event of Illinoian time. The cases in which bowlder clay appears in the lower outwash may be attributed, perhaps, to blocks of ice or even tongues of ice advancing part way down the valleys.

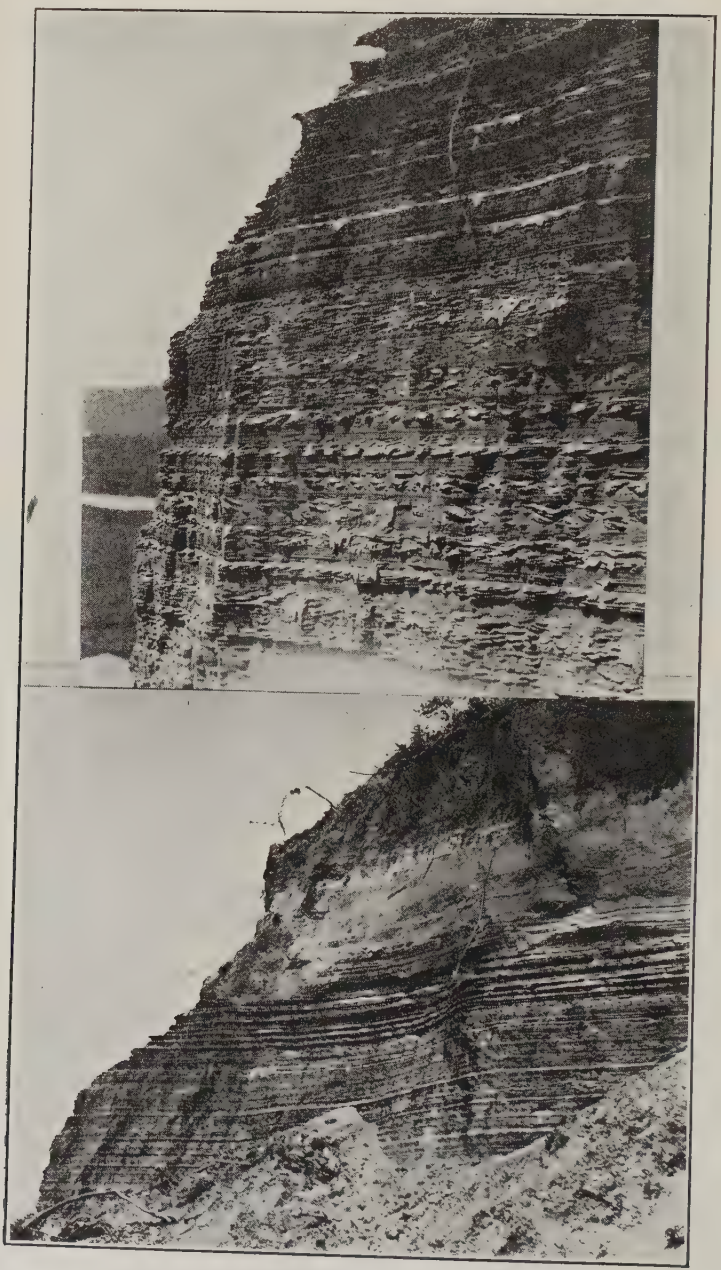

FIGURE 2. (Lower.) Deposit of fine sand interbedded with coal and mica, and covered with bowlder clay.
FIGURE 3. (Upper.) Finely laminated sand showing cross-bedding.

In the main, the Illinoian valley deposits at Cincinnati record a predominant outwash condition followed by a final, general advance of the ice. This is a statement of field observation. If it were not true, it would be a difficult matter to explain the existence of a practically level and concordant terrace of Illinoian age, abutting sharply against the valley walls which rise 200-250 feet higher. This can be seen in dozens of instances near Cincinnati.

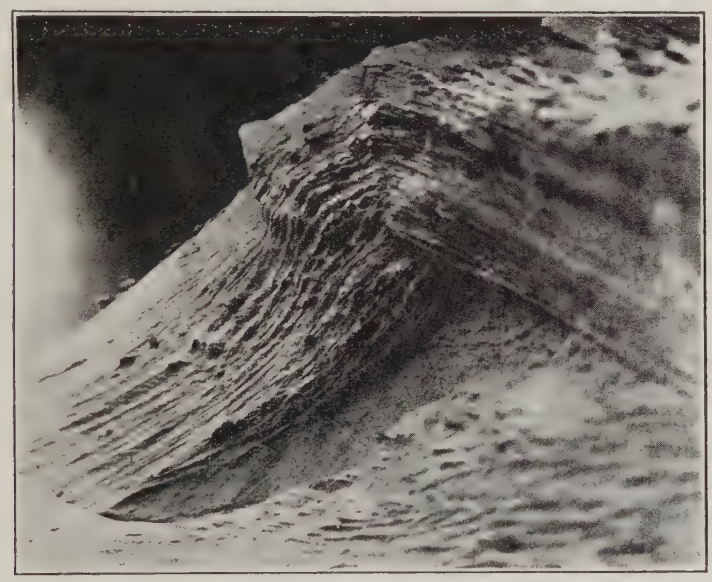

FIGURE 4. Fold in laminated sand.

OCCURRENCE OF COAL AND MICA.

It is in the fine sand between the cemented zone at 535′ A. T. and the limonite cement at 575′ A. T. that coal and mica occur abundantly. Nearly all the bedding planes are lined with black and some bands as wide as two inches are more coal than anything else. Also interbedded with the coal is an abundance of small mica flakes. This necessitates a common source of supply for both mica and coal. Rounded coal pebbles, usually small, but up to three inches in diameter are plentiful. These are very fragile and crumble in one's fingers when they are removed from the deposit where they lie imbedded. It seems doubtful whether any identification would be possible.

PROBLEM OF ORIGIN.

We have to do clearly with outwash from a coal field somewhere. It is also clear that coal is too fragile a sediment to be transported far in the form of pebbles. However, there are no coal beds in southwestern Ohio and no mica.

The nearest coal fields and the possible sources for such a supply seem to be three:

(1) There is coal in the syncline of Michigan. It is most unlikely, however, that any drainage except drainage from the melting ice ever could have found its way from Michigan into the Ohio river valley. It might possibly have been carried in the ice from Michigan and washed by the water in front of the ice into this valley deposit where it is now to be seen. However, this would be a long and devious journey for coal to endure. It seems probable, therefore, that we must look in another direction than that from which the ice came for the source of this Pleistocene deposit.

(2) The Licking river rises in the coal fields of eastern Kentucky and the sandstones associated with the coal beds are often rich in mica flakes. If the headwaters of the Licking can be shown to have discharged along the line of the ancestral Ohio instead of through the Cincinnati basin, as stated by Dr. Leverett,[1] it could have brought the coal, as well as the mica. The wash of its current, however, is badly needed to explain part of the water-cut rim of the Cincinnati basin, (Fig. 1, d) unless we wish to assume that this was carved chiefly in post-Illinoian time. One fact, at least, might serve to support such a view—that there are no remnants of Illinoian terrace anywhere in the basin.

However, if the Licking brought the coal and mica into the old northward curve of the ancestral Ohio, no drainage pattern has yet been traced which would make it possible.

(3) The most plausible origin for the coal and mica deposited near the mouth of the Little Miami seems to be the coal fields of southeastern Ohio, though the distance is greater than one would wish. It might have been carried westward by the Ohio at a time before the old valley trending northward through Madisonville and Norwood had been abandoned. The sand below the bowlder clay would thus be an old Ohio river deposit, not outwash from the ice at all.

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[1]Leverett, Frank. Monograph XLI, U. S. Geol. Sur.

Whatever drainage brought the coal must have continued until the final advance of the Illinoian ice, because the coal and mica continue upward in the deposit almost to the level of the bowlder clay on top. Just above the sand, as stated earlier, are finely laminated beds of clay and these are followed by bowlder clay. As the ice advanced down the old valley from the north, it must have dammed the northward flowing river, causing the deposition of lake beds during a time of temporary ponding. This was followed by the actual advance of the ice which changed the course of the stream to its present east-west direction.

TIME OF BREAKING OF THE DIVIDE AT MANCHESTER, OHIO.

Dr. Leverett says[2] that certain topographic features, chiefly gradation plains and relative widths of valleys, indicate that the divide at Manchester, Ohio was broken at the time of a pre-Illinoian glaciation, while the northward curve of the Ohio at Cincinnati probably continued until Illinoian time. If the laminated sand of this deposit is to be interpreted as a river-laid deposit, built up higher and higher as the advancing ice dammed the northward flowing stream, it is certain, as stated above, that such a drainage continued until the final advance of the ice in Illinoian time. If the coal and mica were transported by the Ohio from the east and not by the Licking from the southeast, it is certain that the Manchester divide had been broken before this deposit accumulated. There is neither coal nor mica west of Manchester.

Hence this one exposure, if it be interpreted correctly, proves definitely that the Manchester divide was broken earlier than the drainage changes were effected at Cincinnati and that the drainage changes at Cincinnati were not brought about until the final advance of the Illinoian ice.

It would also definitely date the breaking of the divide at Manchester as pre-Illinoian, in accordance with Dr. Leverett's evidence, except for one circumstance. This presents an alternative. There is no coal in the lower part of the deposit. It is not impossible that the divide was broken in early Illinoian time and that the old course of the Ohio at Cincinnati was maintained until the last event of the Illinoian. However,

[2]Leverett, Frank. "Pleistocene of Northern Kentucky." Ky. Geol. Sur., Series VI, Vol. 31, 1929.

as Dr. Leverett points out, an enlarged Ohio must have cut the very wide Norwood trough (1½ to 2 miles) and not a little stream heading seventy miles to the east which has left old loops not wider than one-fourth to one-third mile. Such a large stream, at work during the long inter-glacial time preceding the Illinoian, could more reasonably be credited with completing the wide and deep (365′ A. T.) valley, and into such a valley it could have carried the coal and mica as its current was slackened by the approach of the ice. The coal and mica constitute a near-proof, if not a proof, of this bit of chronology.

OTHER PLEISTOCENE DEPOSITS IN THE VALLEY OF THE PRESENT OHIO.

Two miles south of the terrace described above and within a distance of two miles eastward along the north side of the present Ohio river, (Fig. 1, e) there are four good exposures of glacial material showing cross sections of 100 feet or more. Though these are so near, though they lie in the same valley which was used presumably by the ancestral Ohio, and though they are of about the same level, with water-laid material below and bowlder clay on top, they are obviously very different in origin. The outwash material forming the lower two-thirds or thereabout is largely heavy gravel and sand with coarse cross-bedding, and carrying an abundance of granite, diorite, and other Canadian pebbles. There is no coal or mica.

It is hardly possible that the same stream could have deposited at the same level, at the same time, coarse, cross-bedded gravel at one place and the finest laminated sand not more than two miles farther along its course. Besides, there seem to be no Canadian pebbles in the sand near the Miami. Clearly the two deposits are not parts of the same unit, though the valley is continuous and is thought to have been used in pre-Illinoian time by the same stream.

Some satisfactory explanation must be found. If the deposit near the Miami is in large part a terrace built by the ancestral Ohio river and the concordant terrace exposures along the present Ohio are composed largely of glacial outwash, the latter must have replaced the former in that part of the valley occupied at present by the Ohio river. As the ice advanced, covering the river-laid deposit with bowlder clay, there came a time when the ponded water spilled over the

divide to the west and established the present east-west course of the Ohio river past Cincinnati. This would have furnished a straightened course for the major stream and a natural outlet for the immense volume of ponded water. The heaviest outwash would have been carried into the major valley and the quickened velocity of the water would have carried out the finer sand, which had accumulated in earlier Illinoian time, and would have substituted the glacial outwash for the river-laid sand.

This would seem to the writer a satisfactory explanation of the anomalous data. It is supported by this further fact, that coal and mica are found interbedded with a similar fine sand exposed at Ivorydale near Winton Place, which lies in the northward continuation of the abandoned valley of the ancestral Ohio. (Fig. 1, f.) In the Ivorydale sand there is less of coal and mica, but the fineness of the material and the regularity of the bedding are very similar to that exposed near the Little Miami. The deposits are apparently bits of the same terrace with the same origin.

CONCLUSION.

The occurrence of an abundance of coal and mica interbedded with fine sand in the abandoned northward curve of the ancestral Ohio demands a source of supply for such foreign materials. The most plausible place from which they could have been derived seems to be the coal fields of southeastern Ohio. If this be the origin of the material, and the pre-Illinoian Ohio river be the agent of its deposition, the filling of the abandoned "Norwood trough" is here, at least, largely a river terrace of Pleistocene age rather than a deposit of material derived from the glacier.

If the ancestral Ohio brought the coal and mica, it must have had its source at that time east of Manchester, Ohio, because there is neither coal nor mica west of Manchester. The divide at Manchester must, therefore, have been broken before this terrace of Illinoian age was built, and it must have been in the building until the final advance of Illinoian ice.

THE DAILY PERIODICITY OF TRANSPIRATION IN THE TULIP POPLAR LIRIODENDRON TULIPIFERA L.*.

BERNARD S. MEYER.

Although a large number of papers have been published describing investigations upon the daily periodicity of transpiration in herbaceous plants very little information appears to be available upon this subject for ligneous species. There are almost no critical data of this sort for the important tree species of the deciduous forests of eastern North America. In this investigation the daily transpiration periodicity was studied in young tulip poplars (*Liriodendron tulipifera* L.). This species plays an ecologically important role over large portions of the eastern deciduous forest area. It is an important timber tree throughout much of its natural range, and has many advantages as a species for reforestation projects in suitable habitats. Hence studies on the fundamental physiology of this species appear to be desirable. A knowledge of transpiration rates and periodicity are necessary as integral parts of any study of the water relations and requirements of this or any other species.

A review of the more recent literature on transpiration reveals a few papers which have a direct bearing on this general problem. Dole (1924) determined the daily periodicity of transpiration in the white pine (*Pinus strobus* L.). In this investigation potted plants growing in a well watered soil were used. When grown in an uncontrolled atmospheric environment such plants showed a regular cyclical periodicity of transpiration with the maximum at about 1 P. M. and a very low rate during the hours of darkness. The effects of differences in the water content of the soil, temperature, and relative humidity upon the rate of transpiration were also investigated.

Wilson (1924) determined the daily periodicity in transpiration rates for a large number of Australian xerophytes, including a number of ligneous species. He also used potted plants growing in well watered soils. The peak of the transpiration

*Papers from the Department of Botany, the Ohio State University, No. 283.

curve for the ligneous species, almost without exception, was found to occur in the middle part of the day, that is, between the hours of 11 A. M. and 3 P. M. In most of the species studied the night rates of transpiration were very low. These results are in general accord with published records of transpiration periodicity in herbaceous species.

Several field studies of the transpiration periodicities in ligneous species have been made by means of one from or other of the hygrometric paper method. Cribbs (1919, 1921) studied the daily march of "transpiring power" in the basswood (*Tilia americana* L.) by such a method. The results for trees growing in a number of different habitats were compared and considerable attention was paid to the effects of various environmental factors. The maximum rate of water loss was found to occur at different times of the day depending upon the habitat of the trees, and the diurnal march of atmospheric factors. In general, however, a cyclical diurnal variation in the rates of water loss was found for this species.

Meyer (1927) determined the transpiration periodicity for six species of Ohio trees and shrubs *in situ* by a modified form of the hygrometric paper method. In all of these species the maximum rate of water vapor loss as indicated by this method was found to occur relatively early in the day, usually between the hours of 8 and 10 A. M.

Blaydes (1928), using the same method as Meyer, studied the daily periodicity of transpiration in a number of species of plants native to Ohio, including several trees and shrubs. His results also show that the maximum rate of water vapor loss usually was attained during the mid-morning hours.

The hygrometric paper method, as commonly employed, does not measure transpiration in the usual sense of the word, but merely the ease with which the leaves of plants will lose water vapor to a standardized environment. The effects of diurnal variations in the atmospheric factors are largely or almost entirely eliminated. Because of its obvious advantages in the field this method has been widely used, but its limitations should be clearly realized. Apparently the general type of curve obtained by the hygrometric paper method differs somewhat from the general type obtained when the method of weighing potted plants is used. The latter method almost always indicates a transpiration peak in the middle part of the day, while the former more often indicates a peak in the curve

during the morning hours. It is clear, on theoretical grounds, that this difference is in part due to inherent differences in these two methods of measuring transpiration. However, it also seems almost certain that there are also real differences between the transpiration periodicities of plants growing under certain field conditions, and those growing in watered pots. A careful analysis of the exact methods used and the conditions under which the plants were growing is obviously necessary in evaluating results of this kind. A discussion of some of the limitations of the hygrometric paper method will be found in a previous paper by the author (1927).

The purpose of the present investigation was to study the daily periodicity of transpiration in the tulip poplar, and to obtain some approximate data, at least, on the magnitude of the daily transpiration loss from this species under the conditions of a fairly "typical" central Ohio summer day. The method chosen for the measurement of transpiration was that of weighing potted plants, which appears to be the most satisfactory method which is readily available for the determination of the daily periodicity in transpiration rates. The water content of the soil in the pots was maintained at approximately the moisture equivalent percentage. The results of the investigation represent, therefore, the daily periodicity curve for transpiration in young tulip poplars on a representative summer's day under conditions in which soil moisture deficiency, in itself, was probably not a limiting factor.

METHODS.

The tulip poplars used were grown especially for this investigation. Seeds of the 1928 crop were stratified over winter and sown in flats the following spring. About twenty-five of the resulting seedlings were later selected and each transplanted into a weighed earthenware pot 10 cm. in top diameter, and of known weight. Each of the pots was provided with 500 gm. of air dry loam soil which had a moisture equivalent value of 22.

After the transplanting of the seedlings was completed the pots were sunk for about one-third of their height in sand in a frame which was located out-of-doors. The sand matrix in which the pots were imbedded was watered from time to time during the growing seasons but otherwise the plants were exposed to the normal environmental conditions. The plants remained

in this location from early in the summer of 1929 until August 10, 1930. They had therefore completed practically two growing seasons before they were used in the present investigation.

For the specific purposes of this investigation seven plants were selected from the group, all closely similar in height and general appearance. These plants had stems about 15 cm. high and total leaf areas of between 2 and 3 square decimeters.

At about 7:00 P. M. on August 10 these pots were removed to an indoor bench, carefully brushed free from sand and allowed to stand until their outer surface had dried. Each pot was then fitted into a weighed metal shell and this set-up in turn weighed. A simple calculation then made it possible to add to each pot just sufficient water to bring the water content of the soil in that pot up to its moisture equivalent percentage.

This calculation was made possible by the fact that the weights of the shell, pot, and dry soil were known. The weight of the plant and the weight of the water held in the walls of the pot when in equilibrium with the same type of soil at its moisture equivalent were also known quite accurately from determinations on similar plants and pots.

As soon as the added water had been absorbed by the soil its surface was covered with a disk of cardboard, so cut that it fitted the inside walls of the pot snugly. This disk was cut radially to a central aperture through which the stem of the plant passed; a second aperture was provided through which a glass watering tube was inserted into the soil. This tube was provided with a rubber stopper. The stem of the plant was wrapped with cotton at the point where it protruded above the cardboard and this in turn covered with grafting wax. The entire soil surface as well as the gap between the rim of the pot and the rim of the metal shell was then sealed over with a layer of plastic clay. Finally the top of the pot was covered with a tinned metal disk which was radially cut to a central aperture to provide for the stem of the plant and was also supplied with an aperture through which passed the glass watering tube.

As soon as each pot was completely assembled it was weighed. Just before the experiment began each pot was reweighed and any loss of water which had occurred between the two weighings was restored.

At 10:00 P. M. on the evening of August 10 the seven potted plants were moved out into an open spot in the Botanical

Garden of the Ohio State University and supported on an especially built frame so that the metal shells would be shielded from any direct sunlight, without interfering in any way with the exposure of the plants. The next weighing of the pots was not made until 4 A. M. on the morning of August 11; weighings then followed at two hour intervals until 12 P. M. on this latter date. After each weighing any water which had been lost by transpiration was restored to the pot in units of 1 ml. The pots were always replaced in the frame so that the orientation of the leaves with respect to the environment remained unchanged throughout the 24-hour period.

A parallel series of determinations was made of wet and dry bulb thermometer readings, soil temperatures, light intensity, and wind velocity. The wet and dry bulb readings were obtained with a sling pyschrometer in the standard way. Soil temperatures were measured by thermometers set in the soil of two of the pots. The average reading of the two was recorded. These thermometers were calibrated against each other and with the psychrometer thermometers just before the series of determinations began.

Relative light intensity measurements were made with Eder-Hecht "Graukeil" photometers using Solio paper. It is recognized of course, that this method of photometry is subject to all the errors of any method in which sensitized paper is used and in which the surface exposed to the light is flat and horizontally placed. In spite of the known limitations of this method it gives, under the conditions under which it was used in this investigation, a fairly reliable indication of relative light intensities. The numerical values obtained with the instrument as used are of relative significance only. The photometers were exposed for full two hour periods, so that each value represents an integration of the light intensities for a two-hour period.

The wind velocity was measured by means of a wind meter which was oriented in the direction of the maximum wind velocity for 5-minute intervals once every two hours. The prevailing winds during the course of the experiment were from the north and northwest.

In general the day chosen for the determinations was a "typical" Ohio summer day except that the temperature was not quite as high as usual at this season. The day was clear, except for a very high thin film of cloud which passed across a

portion of the sky between the hours of 1:30 and 4:30 P. M. During a portion of this period this thin cloud was across the line of direct sunlight. According to the photometer readings, however, this cloud was too insubstantial to have any appreciable effect on the relative light intensity falling on the earth's surface.

At the conclusion of the experiment, determinations were made of the total leaf blade area for each plant, and also of the fresh weight and dry weight of the leaf blades for each plant. The main stem and petioles were both disregarded as transpiring surfaces in the final calculations, preliminary experiments with plants which had had the leaf blades stripped from them having shown that the magnitude of the transpiration from surfaces other than the leaf blades was less than the experimental errors in the method used.

DISCUSSION.

Table I presents in detail the data obtained concerning transpiration rates. These data are based on measurements made, except during a part of the first night, at two-hour intervals. They have been computed upon four different bases: grams of water transpired per plant, per square decimeter of leaf surface, per gram of fresh weight of the leaves, and per gram of dry weight of the leaves. The mean two-hourly value for the seven plants has been computed and also the total daily transpiration for each plant, as well as the mean for the total transpiration.

The figures presented in this table give a fairly definite conception of the quantitative values for the amounts of water transpired by young tulip poplars under what for the lack of any more precise term are here called "typical" Ohio mid-summer meteorological conditions. The figures as given on the basis of transpiration per plant are probably of greatest significance from the ecological standpoint. Although the variability in transpiration rates for these apparently similar plants, all growing under the same set of external conditions is striking and the number of plants used is insufficient to permit of statistical treatment, nevertheless the results would appear to be quite indicative of the amounts of water transpired by young trees of this species. The average total transpiration per plant was found to be 25.4 grams per day. Since soil water conditions were favorable this does not represent a minimum

transpiration rate for this species, but probably does represent the approximate transpiration rate under conditions suitable for growth.

TABLE I.

DAILY VARIATIONS IN THE TRANSPIRATION RATES OF TWO-YEAR OLD TULIP POPLARS.

Plant		August 11, 1930					Noon						Total
		12–2	2–4	4–6	6–8	8–10	10–12	12–2	2–4	4–6	6–8	8–10	10–12	
		Grams Water Lost per Plant												
1		0.1	0.1	0.2	0.9	5.0	6.1	5.2	3.9	4.1	2.7	0.3	0.2	28.8
2		0.2	0.2	0.3	1.0	3.5	4.2	3.7	3.6	3.6	2.5	0.3	0.2	23.3
3		0.3	0.3	0.3	1.5	3.9	4.6	4.1	3.0	2.8	1.9	0.4	0.3	23.4
4		0.2	0.2	0.2	1.4	4.2	4.4	4.0	3.6	3.6	2.0	0.3	0.3	24.4
5		0.2	0.2	0.3	1.6	3.9	3.8	3.7	3.0	3.2	1.6	0.3	0.2	22.0
6		0.3	0.3	0.5	2.0	5.2	6.7	6.4	5.2	4.8	2.1	0.7	0.2	34.4
7		0.3	0.2	0.2	1.6	4.1	3.5	3.5	3.2	3.1	1.6	0.3	0.1	21.8
Mean		0.2	0.2	0.3	1.4	4.3	4.8	4.3	3.6	3.6	2.1	0.4	0.2	25.4
	Leaf Area Dm_2	Grams Water Lost per dm_2 of Leaf Surface												
1	2.73	.04	.04	.07	.33	1.80	2.23	1.90	1.43	1.50	.99	.11	.07	10.51
2	2.08	.10	.10	.14	.48	1.68	2.02	1.78	1.73	1.73	1.20	.14	.10	11.20
3	2.61	.11	.11	.11	.57	1.49	1.76	1.57	1.15	1.07	.73	.15	.11	8.93
4	2.58	.08	.08	.08	.54	1.63	1.70	1.55	1.39	1.39	.78	.12	.12	9.46
5	2.79	.07	.07	.11	.57	1.39	1.36	1.33	1.08	1.14	.57	.11	.07	7.87
6	2.57	.12	.12	.19	.78	2.02	2.61	2.49	2.02	1.87	.81	.27	.08	14.38
7	2.57	.12	.12	.08	.62	1.59	1.36	1.36	1.24	1.20	.62	.12	.04	8.47
Mean	2.56	.09	.09	.11	.55	1.66	1.86	1.70	1.42	1.41	.81	.17	.08	10.11
	Fresh Weight Leaves	Grams Water Lost per Gram of Fresh Weight												
1	3.52	.03	.03	.06	.26	1.42	1.73	1.48	1.11	1.16	.77	.08	.03	8.16
2	2.67	.07	.07	.11	.37	1.31	1.57	1.39	1.35	1.35	.94	.11	.07	8.71
3	3.18	.09	.09	.09	.47	1.23	1.45	1.29	.94	.88	.59	.13	.09	7.34
4	3.03	.07	.07	.07	.46	1.38	1.45	1.32	1.19	1.19	.66	.10	.10	8.06
5	3.42	.06	.06	.09	.47	1.14	1.11	1.08	.88	.93	.47	.09	.06	6.44
6	3.32	.09	.09	.15	.60	1.57	2.02	1.93	1.57	1.44	.63	.22	.06	10.37
7	3.27	.09	.09	.06	.49	1.25	1.07	1.07	.98	.95	.49	.09	.03	6.66
Mean	3.20	.07	.07	.09	.44	1.33	1.49	1.36	1.12	1.13	.65	.12	.06	7.96
	Dry Weight Leaves	Grams Water Lost per Gram of Dry Weight												
1	0.78	.13	.13	.26	1.15	6.41	7.82	6.66	5.00	5.26	3.46	.38	.26	36.92
2	0.60	.33	.33	.50	1.67	5.83	7.00	6.16	6.00	6.00	4.16	.50	.33	38.81
3	0.67	.45	.45	.45	2.24	5.82	6.86	6.12	4.47	4.18	2.83	.60	.45	34.92
4	0.57	.35	.35	.35	2.45	7.37	7.71	7.02	6.31	6.31	3.51	.53	.53	42.79
5	0.81	.25	.25	.37	1.98	4.81	4.69	4.56	3.70	3.95	1.98	.37	.25	27.16
6	0.71	.42	.42	.70	2.82	7.32	9.43	9.01	7.32	6.76	2.96	.99	.28	48.43
7	0.67	.45	.45	.30	2.36	6.12	5.22	5.22	4.77	4.62	2.39	.45	.15	32.50
Mean	0.69	.34	.34	.42	21.0	6.24	6.96	6.35	5.37	5.30	3.04	.53	.32	37.36

The diurnal periodicity of transpiration for this species is shown by the curve in Text Fig. 1. This curve is based on the mean two-hourly transpiration based on the square decimeter basis. Exactly the same type of curve would of course result if any of the other bases for transpiration were used.

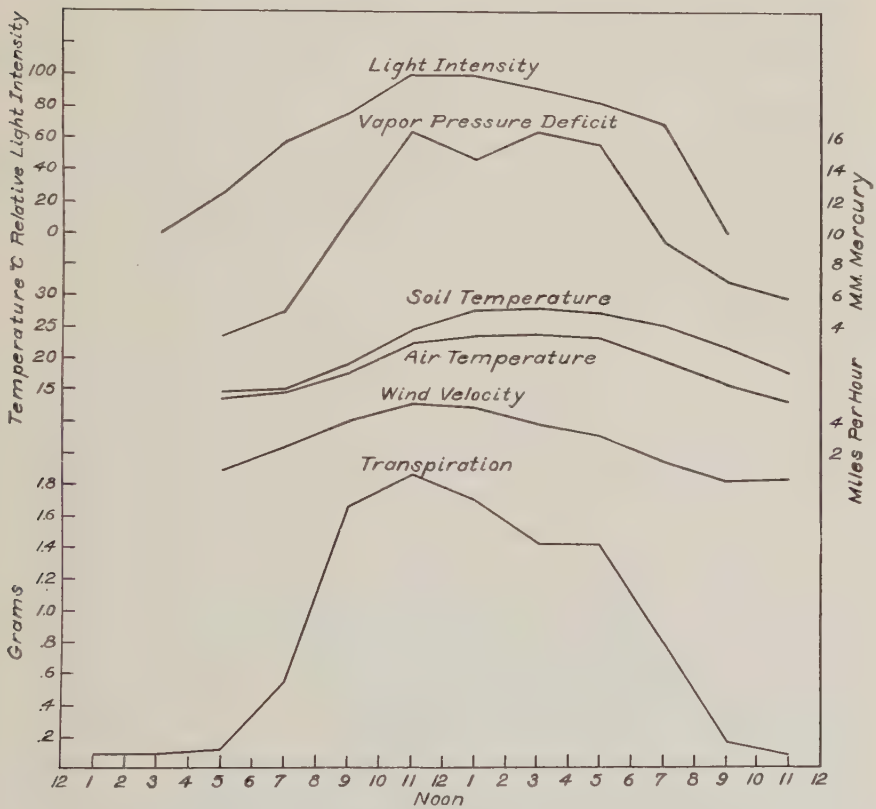

FIGURE 1. Diurnal variations in tulip poplar transpiration and in environmental factors.

Curves are also included in Text Fig. 1 for the daily periodic variation in the vapor pressure deficit, relative light intensity, soil and air temperature, and wind velocity. The vapor pressure deficit data were calculated from the wet and dry bulb thermometer readings.

A detailed discussion of the results does not appear to be necessary. In general the curve for the rate of transpiration is symmetrical, although it shows a slightly skewing towards

the morning hours, and there is a tendency for the curve to flatten out for a period during late afternoon. Transpiration during the hours of darkness is almost negligible and may be assumed to be entirely cuticular. The rate begins to rise between the hours of 5 and 6 in the morning, rises very rapidly between the hours of 7 and 9, reaches a peak about 11, declines slowly but mostly consistently until 5 P. M. after which the decline in rate is very rapid until the practically stable night rate is attained, apparently some time between the hours of 8 and 10 P. M.

This transpiration periodicity curve resembles very closely those obtained for various species of herbaceous plants by Briggs and Shantz (1916), Sayre (1919), and others, all of whom used methods very similar to those employed in the present investigation. It seems probable that the diurnal transpiration periodicity in woody plants is, in general, similar to that found in herbaceous plants growing in similar habitats.

The data on environmental factors are plotted graphically, not primarily in an attempt to explain the transpiration periodicity in this species, but rather to define in quantitative terms the environmental conditions to which the plants were subjected during the course of the experiment. Attempts to trace a causal relationship between the daily periodicity of transpiration and the daily periodicity of certain environmental factors have been made by a number of investigators, including some of those previously mentioned (Briggs and Shantz, 1916, and Sayre, 1919). A detailed analysis of the cause of transpiration periodicity is beyond the scope of this paper. The most definite correlations in these experiments are between transpiration periodicity and the daily periodicity of light intensity and to a somewhat less degree the daily periodicity in the vapor pressure deficit. This result would be anticipated on theoretical grounds. Light is the primary factor concerned in the opening and closing of the stomata. The vapor pressure deficit theoretically comes the closest of any readily determined environmental measure of indicating the steepnees of the diffusion gradient through the stomata.

Most of the recorded investigations of the daily periodicity in the transpiration rate in plants have been conducted with potted plants. Although this method offers many advantages from the experimental standpoint it is extremely doubtful if the results obtained always indicate the usual transpiration

rates as they occur in plants growing under field conditions. The customary procedure, which has been the one followed in the present investigation, has been to provide the plants with favorable soil water conditions, and usually to maintain at least an approximately constant percentage of water in the soil during the course of the experimentation. Such soil water conditions are not always present under field conditions. The available soil water is very apt to be deficient, and is probably often a limiting factor in transpiration. Daily variations in the amount of water present may also occur in natural soils. It seems certain, therefore, that because of these rather fundamental differences in soil water supply, that the daily periodicity curve for plants rooted in a natural soil will often differ from that obtained with potted plants in which the pots are well supplied with water. A difference in magnitude of the transpiration rates is certain, and differences in the trends of the curves might also occur. Of course, when a natural soil is supplied with water to approximately its moisture equivalent percentage there is every reason to believe that the transpiration curves for the plants growing in that soil and the curves for plants grown in pots containing the same soil and under the same soil water conditions would be essentially the same.

SUMMARY.

This paper reports the results of a study of the daily periodicity of transpiration in young tulip poplar trees on a "typical" Ohio summer's day. Transpiration was measured by the method of weighing potted plants. The soil in the pots was maintained at approximately the moisture equivalent percentage. Transpiration rates were calculated on four bases: per plant, per square decimeter of leaf surface, per gram of fresh weight and per gram of dry weight. All data are the averages for seven different plants. The results indicate that tulip poplar trees at the end of their second season of growth transpire about 25 grams of water per day per plant under such conditions as those chosen for this experiment. The peak of the transpiration curve was found to occur a little before midday. The maximum rate of transpiration recorded was 4.8 gms. per plant for the two-hour period between 10:00 A. M. and 12:00 M. Transpiration during hours of darkness was low and can be assumed to be entirely cuticular. In general, the transpiration periodicity for this species is similar to that

which has previously been described for a number of other species, mostly herbaceous. Measurements were also made of the daily march of soil and air temperatures, light intensity, wind velocity, and vapor pressure deficit. Of the environmental factors only the light intensity and vapor pressure deficit periodicity showed close correlation with transpiration periodicity.

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Are Healthy People Interested in Health?

It would be simple enough to sell ideas of health to the inmates of a hospital or sanitarium, but to do the same to a group of college students who, as a rule, have plenty of health, is a different task and requires a super sales talk. It is of primary importance, however, that this very group of healthy youngsters become interested in preserving that which they already have.

In their recent book, "Fundamentals of Health," Kirkpatric and Huettner have attempted to utilize those phases of biology which their experience has shown them to be of most interest to their students. Capitalizing upon this interest they have made use of it as a basis for presenting their "fundamentals" for health.

For the most part the book is very well done. The opening chapter on the "Evolution of Man" is the weakest. The attempt to develope an evolutionary background is often teleological and unsound. But the book contains much of value upon foods, embryology and reproduction, immunity and immunology, public health relations, etc. The matter of sex is especially well treated in a frank and open manner as it should be.

Diagrams, cuts and tables are profusely used to advantage. There is an excellent list of references for further reading with each chapter and a glossary of terms which should be useful to the student.

Fundamentals of Health, by KIRKPATRIC AND HUETTNER, 8 vo.: VII, 576 pp., Ginn and Company, 1931.

FLOWER PRODUCTION IN THE LEMNACEAE.*

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The general evolutionary movement in the Lemnaceae or duckweeds apparently has been from frequent flower production to rare flower production to a total loss of the ability to produce flowers. From the original ancestral forms, which perhaps depended entirely upon seed production for propagation, have evolved these minute plants which now are propagated almost entirely or solely by vegetative methods. The family consists of four genera and about 26 known species.

In *Spirodela* flowers are very rarely produced. Wiggers, 1780 (36), records the first discovery of *Spirodela polyrhiza* (L) Schleiden in flower by Grauer, a young botanical student. Flowers of this species were first discovered in the United States at Staten Island, N. Y., by Leggett, 1870 (22a). Others who have recorded flowering are Willdenow, 1805 (37), Schleiden in Germany, 1839 (30), Griffith in India, 1851 (14a), Nees von Esenbeck as recorded by Hoffman, 1840 (17) and Ludwig, 1909 (24b), Gillman, Belle Isle, Detroit River, Michigan, 1871 (13b) and 1881 (13c), Rostowzew, 1901 (28a) and Saeger in Missouri, 1929 (29). *Spirodela punctata* (Meyer) Thomp., collected by the Capt. Wilkes Expedition in Terra del Fuego, South America in 1839, was described as flowering by Thompson, 1898 (31). Flowers of *Spirodela oligorhiza* Kurz were described by Kurz, 1865 (21). A fourth species found in Australia, *Spirodela pusilla* Hegelm, apparently flowers more commonly. than any species of the genus, Hegelmaier, 1895 (15a).

The flowers and even matured fruits of *Lemna* have been found occasionally in all species and many have been studied in detail. Micheli 1729 (25) first records flowers of *Lemna gibba* L. Ehrhart, 1779 (9), Wolff, 1801 (39), Palisot, 1816 (26), Wilson, 1830 (38), Brongniart, 1833 (4), Richard, 1833 (27), Schleiden, 1839 (30), Dalgleish, 1926 (16), and a number of other authors have recorded flowers of this species. *Lemna trisulca* L. apparently was first reported in flower by Wolff,

*Papers from the Department of Botany, Ohio State University, No. 295.

1801 (39) and had since been found flowering under natural conditions by a number of authors. *Lemna perpusilla* Torrey was first described and also found in flower at Staten Island, N. Y., by Torrey, 1843 (32), and again by Leggett, 1870 (22a), and studied in detail by Blodgett, 1914 (2a) and 1923 (2b).

Lemna minor L. was the only duckweed known in flower to Linnaeus, 1763 (23). This species undoubtedly blooms more frequently than any other as it has been reported in the flowering condition by no less than thirty authors. Some flowering plants were observed by the writer during the summers of 1928, 1929, 1930 and 1931. In May, June, July, August and September of the drowth period of 1930, flowering plants were found in abundance in many widely separated localities of Ohio. Wolff, 1801 (39), Vuyck, 1895 (34a), Kalberlah, 1895 (19), Rostowzew, 1901 (28a) and 1905 (28b) and Goebel, 1921 (14) gave detailed descriptions of the reproductive structures. Caldwell, 1899 (5), made a complete life history study of the species.

Flowers in the genus *Wolffia* are extremely rare, difficult to detect because of their small size, and have never been found for two species, W. *microscopia* Griff. and W. *cylindracea* Welw. W. *papulifera* Thomp., a species known only from Missouri and bordering states and described by Thompson in 1897 (see 1898, 31), was unknown in flower until discovered by Saeger in 1927 and 1928 (see 1929, 29). Flowers of W. *brasiliensis* Weddell were first described by Weddell, 1849 (35), W. *arrhiza* (L) Wimmer by Franchet, 1864 (12), W. *hyalina* (Delile) Hegelm., by Hegelmaier in 1865 (15), W. *columbiana* Karsten by Karsten in 1865 (20) and by Austin, 1870 (1), W. *repanda* Hegelm. by Hegelmaier in 1868 (15b), W. *Wetwitschii* Hegelm. by Hegelmaier in 1868 (15b), and W. *punctata* Griseb. mentioned or described vaguely by several writers. Additional known occurrences of flowering in the genus are certainly rare as the writer was able to secure very few other definite records in making an exhaustive survey of the literature.

In the genus *Wolffiella* reproduction is entirely by the vegetative method as none of the four known species (W. *floridana* (J. D. Smith) Thomp., W. *gladiata* Hegelm., W. oblonga (Ph) Hegelm., and W. *lingulata*) have ever been observed in the flowering condition. The ability to produce

flowers apparently has been so completely lost that probably they are never produced by plants in nature. In *Wolffiella floridana*, at least, it is even doubtful as to whether the flowering potentiality could be made to find expression as the result of favorable physiological conditions.

It has been noted by the writer a number of times and by others (Gillman, 13a, Leggett, 22b, and Saeger, 29), that bodies of water having one flowering species are likely to also have a second or a third. Apparently then, even in nature, unusual combinations of either chemical or non-chemical environmental factors may develop locally in a small body of stagnant water, and make possible the expression of the flowering potentiality which still exists in *Spirodela*, *Lemna*, *Wolffia* and perhaps in *Wolffiella* as well. These necessary combinations do not commonly occur, but certain species, such as *Lemna minor* and to a lesser extent L. *trisulca*, are much more responsive to these effects than the other members of the family.

During the drowth period, or the months of May to September inclusive, of the summer of 1930, dozens of small bodies of water supporting duckweed populations dried up completely or were greatly decreased in size. In a number of these habitats, the water supply failed for what, certainly, was the first time within recent history or perhaps since the settlement of this state. All aquatic vegetation was subjected to most unusual growth conditions. In many shallow pools, duckweeds of several species were left stranded on mud flats with a steady but limited water supply. In other cases, the lowering waters left tangled masses of *Lemna* or *Spirodela* draped about stems of *Cephalanthus occidentalis* or other aquatic shrubs. If the plant mass dipped into the water beneath, a limited but sufficient water supply for life was maintained. During this period some field work was done in each one of the 88 counties of Ohio. Under these conditions two species were found in flower in a number of widely separated localities of Ohio from May 20 to Sept. 6, 1930.

Lemna minor and L. *trisulca* were found in flower at Suffield Bog (Portage Co.), Venice (Erie Co.), Buckeye Lake (Perry Co.), Baumgardner's Pond (Franklin Co.), and Calamus Pond (near Circleville; Pickaway County). In addition L. *minor* alone was found in flower at Jasper (Pike Co.), Athens (Athens Co.), Fredericktown (Knox Co.), Indian Lake (Logan Co.) and

Tamarack Ditch (Williams Co.). No other species were found blooming although large areas of plants growing in more than 180 localities of the state were studied, all of our 7 Ohio species being represented.

In 1928, 1929 and 1931, a similar survey revealed only a few scattered instances of flowering, and then flowering plants were always decidedly uncommon. As to what environmental factors accompanying the drouth, were responsible for the unusual flower production in 1931, can only be a matter of speculation. In many instances, observations suggested that altered mineral content of the water medium, increased water and air temperatures, or light effects might be of most importance.

Flowering plants, without exception, were never found in shaded areas, even though abundant flowering material might be found in better illuminated areas a few feet distant. In most cases, flowers were most abundant in areas most exposed to sunlight. Correlated with this was the observation that flowering plants were invaribly found abundantly only in water areas of unusually high temperatures and were absent in colder portions. In addition, since *Lemna minor* flowered in only about 8% of all of the localities visited, and since the visible environmental characteristics of many localities appeared to be almost the same, it was suggested that the chemical nature or mineral content of the water medium might inhibit or be an important factor in promoting flower production.

In *Lemna minor*, flowering plants observed were usually somewhat above average size for the species, commonly light green in color and with long roots, and invaribly quite cavernous. In *Lemna trisulca*, the extremely modified flowering plants of the species were very light green in color, were quite cavernous and were produced by buoyant plants of medium size having relatively short internodes. With both species, flowering plants produced were similar in general appearance to those previously produced by experimental methods as described below.

In all available literature concerning the Lemnaceae, the writer has found but one reference concerning the production of flowering plants outside of their natural environment. Saeger, 1929 (29), found that cultures of *Lemna minor* growing in dilute mineral solutions (Knop's), sometimes produced

flowers. Other species of *Lemna* grown failed to produce flowers. No references to any experimental attempts to induce flower production, have been found. Therefore, it seemed desirable to make a test of all possible treatments and environmental controls which might alter physiological processes and induce or lead to control of flower production. This paper is largely a revision of a previous paper written in May, 1929, summarizing a series of experiments conducted from Nov. 1928 to May 1929. The writer wishes to acknowledge his indebtedness to Dr. E. N. Transeau and Dr. B. S. Meyer, for their many valuable suggestions and criticisms in this research and to Dr. Robert B. Gordon and Mr. W. C. Camp for their assistance in taking the photographs and microphotographs of flowering plants.

Previous experimental work had demonstrated that there were remarkable differences between our 7 Ohio Lemnaceae species in their reactions to various environmental conditions. This suggested that each species might require its own particular treatment or that those influences which had favored flower production in other plant families, might not apply to this one. Each species, perhaps, has reached its own particular physiological level in regard to the possible expression of the flowering potentiality. The factors inhibiting flower production, which have come into the systems of some of the species in the evolutionary process, are perhaps so dominant that they may never be overcome, even under artificial conditions. From the above, it will be seen that the problem of inducing flower production is a very complex one. The writer has been successful in producing flowers in four species and one variety of the genus *Lemna* and in one species of the genus *Wolffia* by experimental methods affecting the physiological condition. Flowers were produced in *Lemna trisulca*, L. *cyclostasa*, L. *minor*, L. *minor* var. *purpureus* L. *minima* and *Wolffia columbiana*.

The experiments showed that for flower production the following conditions are necessary:

1. Healthy mature plants making good vegetative growth and with an accumulation of a food reserve.
2. Some environmental influence which will rather suddenly check normal vegetative growth with the possible diversion of the accumulated reserve to flower production.

3. In some species, such as *Lemna trisulca*, which undergo a marked transformation of the vegetative form at the time of blooming, plants should be selected for treatment which are as near as possible in appearance to the flowering form as such transformations do not come about rapidly. Not all growth forms are equally responsive to experimental treatments.

In all of the experimental work with flower production, *Spirodela polyrhiza*, *Lemna trisulca*, L. *minor*, L. *minor* var. *purpureus*, L. *cyclostasa*, *Wolffia columbiana*, W. *punctata* and W. *floridana* were used. Plants were grown in about 4 inches of water in glazed culture jars of 28 sq. in. of water surface area and under greenhouse conditions. In every experiment attempted, lots of 1000 or more plants of each species were used to make it possible to observe any results produced, on large numbers of individuals. In many cases, smaller cultures of 1 to 25 plants of each species were treated similarly and used as checks. The record of the various experiments attempted with the results obtained is as follows:

1. Mineral Salt Deficiency.—During the experimental work approximately 850,000 plants of all species (about 460,000 of *Lemna minor*) were "starved" by growing in various nutrient solutions known to be deficient in one or more of all of the elements considered essential, in tap water or in various soil-water solutions. The plants became small in size, produced resting forms in many cases and eventually died, but as far as is known, not a single plant produced flowers. The "starvation" process is a gradual checking of vigorous vegetative growth with the loss of any food accumulation or reserve which might favor flower production if present. This method, then, gives no promise of desired results.

2. Nutrients. All of the species were grown in numerous nutrient solutions of varied combinations and concentrations. Many of the unbalanced nutrients produced size reduction or resting forms. Some produced marked modifications of the vegetative form as in *Lemna cyclostasa*. Nutrients with an excess of nitrates or those containing abundant organic matter, usually produced vigorous vegetative growth but without exception, there was no flower production. The following nutrients were also tested: Knop's, Knop-Bottomly, Detmer-Moor, Detmer's, Pfeffer's, Crone's and Shive's. Several others were used in a few instances but no plants grown produced flowers.

3. Photoperiodism. Several of the species made vigorous growth during the reduced light of the winter months if other environmental factors were satisfactory. Seven species were grown for five months under 24 hour light in various media. All produced somewhat better growth than the controls under natural light but *Spirodela polyrhiza* exhibited a marked tendency to develop excessive pigmentation. This species and the Wolffias also produced resting forms freely. When these plants were suddenly changed to shorter light periods, no flower production took place and no other very pronounced modifications occurred. During the winter months, cultures of each species were subjected to 2, 4 and 6 hours of artificial light daily over a three-week period in addition to the normal sunlight period. These cultures made only slightly better growth than the controls under daylight. Flowers were never produced in any of these experiments.

4. Light Intensity. Plants of 7 species were subjected to five different light intensities of artificial light for 2, 4, 6, 8 and 10-week periods by various degrees of shading, with marked effects resulting in the vegetative form as in *Spirodela polyrhiza*, but no plants developed flowers.

5. Chemical Effects. Approximately 60 common chemical substances were added in varying quantities to the media in which six species of duckweeds were growing. Results were negative except in one case. Flowers of *Lemna minor* and L. *trisulca* were abundantly produced by treatment with dilute sodium hydroxide. This treatment failed to produce flowers in any of the other species and often failed to produce them in these species when repeated. In each case, a culture solution with a mat of plants of approximately 28 square inches was treated. A small amount of the dilute sodium hydroxide was added to the medium for several days until a few of the plants showed signs of injury. The amount required varied considerably. Then treatments were stopped. Usually from 1% to 10% of the plants were killed, the remainder nearly or entirely stopped vegetative growth and a few of them were thrown into the flowering condition. The first treatments began March 28, 1929 and the first flowers were discovered on April 15, 1929. Some flower production continued up to May 16, 1929. The mediums gradually became less alkaline and the hydrogen ion concentrations of the mediums at the time for the greatest

flower production on April 22, 1929 is shown. No flowers were produced in any of the check cultures. The records for each culture are as follows:

Species and Collection	First Flowers	Percent of Plants Flowering	p. H. at Time of Flowering
1. *Lemna minor* Coll. at Baumgardner's Pond, Franklin Co., 3–27–29	4–15–29	15%	7.6
2. *L. minor* Coll. at Baumgardner's Pond Bog, 3–27–29	4–17–29	12%	7.21
3. *L. minor* Coll. at Cranberry Is., Buckeye Lake, 3–25–29	4–16–29	26%	7.33
4. Same as No. 2	4–17–29	20%	7.43
5. Same as No. 3	4–19–29	10%	7.41
6. *L. minor* Coll. at Westerville, Franklin Co., 3–6–29	4–15–29	20%	7.21
7. *L. minor* from De Land, Fla., 3–1–29	4–16–29	5%	7.35
8. *L. trisulca* Coll. on Cranberry Is., Buckeye Lake, 3–25–29	4–19–29	8%	7.16
9. *L. trisulca* Coll. at Baumgardner's Pond Bog, 3–27–29	4–23–29	30%	7.21

6. Ultra-violet Rays. Flowers of *Lemna minor*, L.m. var. *purpureus*, L. *trisulca* and L. *cyclostasa* were abundantly produced in cultures treated with ultra-violet rays from a mercury quartz vapor lamp. Sixteen earthenware culture jars of approximately 28 square inches of water area each were prepared. To each was added a small amount of rich clay loam soil containing considerable organic matter and then filled with tap water. Each jar was given the following duckweed population. The numbers of each are only approximate: *Spirodela polyrhiza* 75, *Lemna trisulca* 100, L. *minor* 150, L.m. var. *purpureus* L. *cyclostasa* 150, Wolffia *columbiana* 400, W. *punctata* 200 and W. floridana 50.

Every other jar of duckweeds was selected as a control and the others were subjected to the ultra-violet treatment. A 110-Volt lamp, at a distance of 30 inches was used. The time

of the treatment of the 8 culture pairs was 8, 16, 27, 39, 51, 63, 75 and 87 minutes respectively. Treatment was given on April 19, 1929 and the first flowers appeared 13 days later on May 2, 1929. Not a single flower was produced in any of the control cultures.

No plants of *Spirodela*, *Wolffia* or *Wolffiella* were thrown into flowering. Vegetative growth of all of the species was almost or completely checked. None of the plants except those of *Spirodela* was visibly affected by the ultra-violet rays. These were usually rather severely burned by the rays in all except those given the 8-minute treatment. The burned plants seemed damaged only on the upper surface. They became heavily pigmented, shriveled and gradually died but were rapidly rejuvinated by the production of vigorous normal plants. All of the L. *cyclostasa* plants producing flowers were small, pale green, decidedly unsymmetrical and with short roots.

The records of each culture are as follows:

	First Flowers Produced	Approximate Percent of Plants Flowering
1. 8-Minute Ultra-violet Treatment		
L. minor	5–4–29	15
L. m. var. *purpureus*	5–2–29	20
L. trisulca	5–2–29	10
L. cyclostasa	5–6–29	3
2. 16-Minute Treatment		
L. minor	5–3–29	30
L. m. var. *purpureus*	5–2–29	25
L. trisulca	5–2–29	15
L. cyclostasa	5–5–29	2
3. 27-Minute Treatment		
L. minor	5–4–29	20
L. m. var. *purpureus*	5–4–29	25
L. trisulca	5–3–29	15
L. cyclostasa	5–5–29	10
4. 39-Minute Treatment		
L. minor	5–4–29	15
L. m. var. *purpureus*	5–5–29	30
L. trisulca	5–4–29	15
L. cyclostasa	5–5–29	10
5. 51-Minute Treatment		
L. minor	5–5–29	10
L. m. var. *purpureus*	5–5–29	30
L. trisulca	5–4–29	5
L. cyclostasa	5–8–29	15
6. 63-Minute Treatment		
L. minor	5–4–29	10
L. m. var. *purpureus*	5–5–29	50
L. trisulca	5–5–29	55
L. cyclostasa	5–8–29	5
7. 75-Minute Treatment		
L. minor	5–3–29	5
L. m. var. *purpureus*	5–5–29	30
L. trisulca	5–6–29	5
L. cyclostasa	5–8–29	10
8. 87-Minute Treatment		
L. minor	5–6–29	2
L. m. var. *purpureus*	5–6–29	10
L. trisulca	5–8–29	3
L. cyclostasa	5–7–29	5

Additional Experiments with Ultra-violet Treatments.

On March 25, 1930, the foregoing experiments with ultra-violet light treatments of duckweed plants were repeated. The same species were used and one other in addition, *Lemna minima* Phillipi, a species not recorded for Ohio. This time the plants were placed 38 centimeters from the light source of the mercury quartz vapor lamp, and by measurement received 86 milliampers on slit No. 3 or 105 ergs per second per square millimeter of area. Treatments of 3, 5, 10, 15, 20 and 25 minutes were used. No attempt to measure or determine the exact quality of the light used was made but the rays proved to be much more destructive than those used in 1929.

The table below illustrates the amount of visible injury to plants in each case:

	Length of Treatment in Minutes					
	3′	5′	10′	15′	20′	25′
Spirodela polyrhiza	Slight effect	Slightly burned	Much burned	Much burned peeled	Very much burned peeled	Very much burned peeled
Lemna minor	No effect	No effect	No effect	Some burned	Burned pale	Epi-dermis peeled
L. minor var. *purpureus*	No effect	No effect	Slight effect	Some burned	Much burned	Burned and peeled
L. trisulca	No effect	No effect	No effect	No effect	Some browned	Much browned
L. cyclostasa	Slight effect	Slightly browned	Browned	Well browned	Much browned	Very much browned
L. minima	No effect	Slight effect	Slightly browned	Browned	Well browned	Much browned
Wolffia columbiana	No effect	No effect	No effect	Slightly browned	Slightly browned	Burned browned
W. punctata	No effect	Slightly browned	Slightly browned	Browned	Much browned	Browned burned
Wolffiella floridana	No effect	No effect	No effect	Slight effect	Slightly browned	Browned

Plants of *Spirodela* receiving 3 or 5 minute treatments continued growth without any flower production. Plants receiving 10, 15, 20 and 25 minute treatments had most of the cells of the upper parts killed. These plants were quickly replaced by budding of new plants from the treated ones, resulting in stimulated vegetative growth, just opposite to the results desired. It is interesting to note that the submerged species were not so severely effected by the light treatments. In the longer treatments, a number of the plants of each species died. Flower production following treatment was very similar to the results obtained during the 1929 experiments except that the percentage of plants producing flowers was less and also the amount of flower production did not always seem to have any definite relation to the length of light treatment received. As before, not a single flower was produced in the untreated cultures. Two additional species produced flowers in the treated cultures.

Spirodela polyrhiza, *Wolffia punctata* and *Wolffiella floridana* failed to produce any flowers. In *Lemna minor* and L. m. var. *purpureus*, from 5 to 20% of the plants receiving 10, 15 and 20 minute treatments produced flowers. In *Lemna cyclostasa*, 1 to 3% of the plants receiving the 5, 10 and 15 minute treatments flowered. In L. *minima*, three plants receiving the 10-minute treatment produced imperfectly developed flowers. Two plants of W. *columbiana* receiving the 15-minute treatment flowered, the first flowers known to have been produced by the species except in very rare instances by plants growing under natural conditions. This species is credited with the distinction of being the smallest flowering plant in the world.

Summary.

1. A review is made of the known occurrences and frequency of flower production under natural conditions in the various species of Lemnaceae.

2. A report is given of observations made upon several Ohio species found flowering under natural conditions.

3. A summary is made of a series of experiments in which treatment was made to induce flower production, through the control of various environmental factors.

4. *Lemna minor*, L.m. var. *purpureus*, L. *trisulca*, L. *minima*, L. *cyclostasa* and *Wolffia columbiana* produced flowers following ultra-violet light treatments. The first three named

also produced flowers following chemical treatment with sodium hydroxyde. No flowers were produced by control cultures in either case.

5. A list is presented of the conditions thought necessary for flower production in the family.

6. Photographs and microphotographs of the minute flowers of two species are presented to show the detailed structure of these parts.

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EXPLANATION OF PLATES.

Plate I.

Vegetative and flowering plants of *Lemna trisulca* L. Ivy-joined or Star Duckweed, produced following experimental treatments.

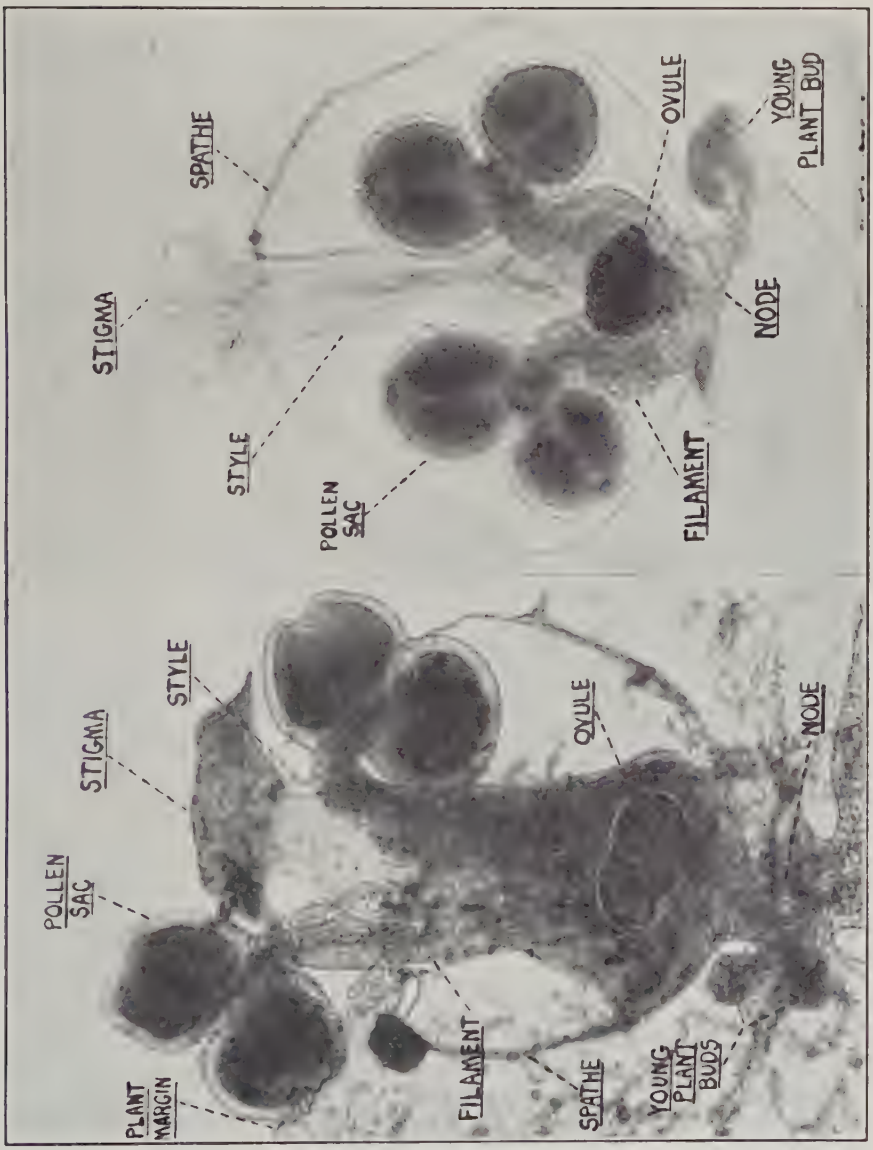
(a) Vegetative plants shown around the margins of the photograph are of the submerged type, being compact in structure and of about the same density as the water medium. The plants are flat, oblong-lanceolate in shape and connected with long internodes, many generations remaining attached forming tangled masses. This growth form is dark green in color, somewhat unsymmetrical in shape with finely serrate margins and usually an acute apex, does not have developed stomata or papules and produces long roots attached at the nodes. Magnification about 3×.

(b) Flowering, floating plants found attached in groups of 3 or 4, (center of photograph). These floating plants are produced by abscission from the submerged vegetative form. They are much smaller and are convexly curved, have very short internodes, are light green in color and decidedly cavernous, having a density of less than one, and develop stomata, but fail to produce roots. Usually one or two of the floating plants of each group produce flowers. The flowers develop from the node, growing out through the plant body, and are monecious, consisting of two stamens with two pollen sacs in each anther and a single flask-shaped pistil, enclosed in a spathe. The anthers are commonly covered with a drop of clear glandular secretion until the opening of the pollen sac.

Plate II.

(a) Left. Microphotograph of a single flower of *L. trisulca* L. showing the spathe, the two stamens with two pollen sacs each and the single flask-shaped pistil. Magnification about 100×.

(b) Right. A flower of *L. minor* L. illustrating the same structures. Note the difference in shape of the spathe pouch in the two species. Magnification about 90×.


PLANT MARGIN
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YOUNG PLANT BUD

THE RELATION OF THE ANT, POGONOMYRMEX OCCIDENTALIS CR., TO ITS HABITAT*

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INTRODUCTION

In spite of the obvious abundance of colonies of *P. occidentalis* in the western section of the United States, our knowledge of the species is somewhat limited. McCook (2) has written quite extensively on this ant and Wheeler (3) has added many bits of valuable information. It is hoped that the following data will bring a clearer interpretation of the species *occidentalis* to those interested, especially as to the relationships existing between the ant and surrounding vegetation.

GEOGRAPHICAL DISTRIBUTION

Pogonomyrmex occidentalis is widely distributed over the far western states with the exception of California, western Oregon and Washington. It is especially abundant in Idaho, Nevada, Utah and Wyoming and generally follows the area of the desert-shrub formation. In Oregon it becomes more scarce with westward progression and I was unable to find it in the western portion of the State. In California it is replaced chiefly by *P. californicus*, especially in the San Joaquin and Imperial Valleys and the Mojave Desert. In Arizona I found it abounding from the Grand Canyon northward. Wheeler (3, p. 565) lists it from Wyoming, Colorado, New Mexico and Arizona; McCook (2, p. 125) from Wyoming, Colorado, New Mexico, Arizona, Utah, Nebraska and Kansas. I have observed it at the following specific localities:

Idaho.—Twin Falls, Rogerson, Pocatello, Nampa, Boise, Blackfoot, Arco, Idaho Falls, Wieser, Mountain Home, Shoshone, Ketchum, Hailey, Redfish Lake, Hagerman, Hammett, American Falls, Dubois, Hollister, Shoshone Falls, Shoshone Canyon, Rock Creek Canyon, Malta, Bliss and Craters of the Moon National Monument.

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Oregon.—Echo, Pendleton, Ontario, Baker and La Grande.
Utah.—Salt Lake City, Delle, Tooele, Grantsville, Snowville, Brigham, Ogden, Zion National Park and Kanab.
Arizona.—Grand Canyon, Williams, Cameron and Lee's Ferry.
Wyoming.—Cheyenne, Laramie, Rawlins, Rock Springs, Green River, Kemmerer, Cody and Ten Sleep.
South Dakota.—Rapid City, Mitchell and Sioux Falls.

Other localities from which *occidentalis* has been reported are as follows:*

Parma, Idaho; 8–29–27; G. W. Haug.
Virginia, Idaho; 7–30–37; G. W. Haug.
Stockton, Kansas; 7–15–20; R. C. Smith.
Custer County, Montana; 7–31–29; R. E. Hutchins.
Woods County, Oklahoma; 7–3–30; R. D. Bird.
Capa, Mobridge, and Newell, South Dakota; H. C. Severin.
Keremeos, B. C.; E. R. Buckell.
Oliver, B. C.; E. R. Buckell.
Okanagan Falls, B. C.; E. R. Buckell.
Osoyoos, B. C.; E. R. Buckell.
Trinidad, Colorado; W. M. Wheeler.
Ash Fort, Arizona; W. M. Wheeler.
Grants, Utah; September, 1917; R. C. Shannon.

McCook (2, p. 126) states that "the vertical distribution of *occidentalis* is probably not much above the altitude of 6,300 feet, which is the height above sea level of the Garden of the Gods," where he studied its habits most closely. Although I have often found the ant above McCook's level, the mounds are always scattered and few in number. This vertical distribution is essentially the same as northward distribution inasmuch as the limiting factors are practically the same in both cases.

STRUCTURE OF THE MOUND

External Structure—Most mounds of *occidentalis* are irregularly conical in outline. McCook (2, p. 127) speaks of them as "elliptical cones," whose shorter faces are about one-half the length of the longer faces. Wheeler (3, p. 291) refers to them as "masonry domes." As a rule the base of the mound is of greater dimensions than the slopes, or faces, but occasionally mounds are to be found with the dimensions very nearly equal. The diameter of the base is usually significant of the size of the colony, but such is not always the rule. Weaker colonies sometimes inhabit larger mounds than those of stronger and more active relatives.

*From the files of M. R. Smith.

Mounds of *occidentalis*, though primarily existing on somewhat level sandy or gravelly areas and exposed to the direct rays of the sun (Fig. 1), are often found on the tops of flat

FIGURE 1. Typical mound of *P. occidentalis* in Western Wyoming, with small crater of *Dorymyrmex pyramicus* in the denuded area. (Original).

FIGURE 2. Pebble mound of *occidentalis* on rock near Twin Falls, Idaho. Note the nest entrance at the base of the mound. (Original).

rocks (Fig. 2), around rocks and around plants (Fig. 3). Rocks often compose part of the base of a mound and upon removing them the various nest chambers and galleries are brought into view (Fig. 4). The composition of the mounds differs greatly and consists of the following chief types:

Average or typical mounds

1. Pebble mounds.
   a. Large pebbles. (Fig. 3).
   b. Small pebbles. (Fig. 2).
2. Sand mounds.
   a. Fine sand. (Fig. 1).
   b. Coarse sand (small pebbles).
3. Earth mounds.
   a. Packed earth.
   b. Loose earth.

Combination mounds

4. Earth and pebbles.
5. Earth and sand.
6. Pebbles and detritus. (Fig. 5).
7. Earth and detritus.

Divergent types of mounds

8. Cinders.
9. Horse or cow dung (dry).
10. Bits of glass and pebbles.

The composition of the mound coverings may be classified as follows:

1. Cinder covering.
2. Frass covering (from harvested seeds).
3. Covering of bits of glass.
4. Covering of twigs or bark.
5. Covering of leaves.
6. Covering of dry horse or cow dung.
7. Covering of sheep, lizard or rabbit dung pellets.
8. Covering of keys from trees (especially ash).

Wheeler (3, p. 202) states that "* * * in *P. occidentalis* the single entrance is situated at the base (of the mound) and almost invariably on the southern or eastern side." Upon examining five hundred mounds in the state of Idaho I obtained the following data:

Number of mounds with one opening	387
Number of mounds with two openings	109
Number of mounds with three openings	4
Number of mounds with opening(s) at base	486
Number of mounds with opening(s) at top	14

Number of mounds with opening(s) on south face....126
Number of mounds with opening(s) on east face.....197
Number of mounds with opening(s) on north face....152
Number of mounds with opening(s) on west face... 25

FIGURE 3. Incipient mound of large, limestone gravel around alfalfa plant near Twin Falls. The bordering vegetation is *Salsola pestifer*. (Original).

FIGURE 4. View of nest chambers of *occidentalis* under rock at base of mound. The white areas are termite galleries. (Original).

The size and shape of the nest openings vary greatly. Some are merely circular holes while others consist of several layers of packed material, giving them a "shelled" appearance.

McCook (2, p. 134) presents excellent descriptions of these openings, or "gates" as he terms them.

For further evidence as to the plasticity of *occidentalis* mound structure I offer the following data. A pebble mound was excavated for the purpose of collecting seeds from the various chambers both in the mound and below the ground level. At the end of six days, upon revisiting the mound, I found that it had been partially rebuilt. The only major difference between the rebuilt mound and the original architecture was the presence of two entrances, one on the east face and one on the west, whereas originally there was only one entrance and that on the southeast face.

Mounds of *occidentalis* do not always occur singly. There are many double mounds and occasionally a triple one. I have never observed more than three mounds within the same denuded area.

Internal structure—The position and numbers of the nest chambers are especially interesting (Fig. 4). The *brood chambers* vary in number and size according to the relative strength of the colonies. Invariably there are present one or more chambers near the surface of the mound where the brood is isolated during the day time (providing the temperature is not too high) and chambers at the base of the mound or under the ground level to which the brood is moved at night or on cooler days. This movement is apparently entirely dependent on temperature fluctuations and will be discussed later. The shape of the chambers varies between colonies and within the same colony as well. The chambers are usually fairly large, averaging 8.5 centimeters, and are irregularly domed with galleries leading to the various adjacent chambers.

The *seed chambers* are especially interesting for there is stored the fruit of the ants' labor. These, like the brood chambers, also vary in number and size, but as a rule they are not abundant and are more or less slit-shaped, being noticeably longer than high. I have found as many as seven and as few as one in a single mound, some overloaded with seed and others containing very little or none. A study of the various seeds harvested has proven interesting and will be dealt with further in the paper.

I have observed many cases in which both brood and seed were confined to the same chambers but this seems to be the

exception rather than the rule. The brood, however, is rarely isolated into separate chambers according to its age but is usually intermingled in the same chambers.

FIGURE 5. Combination mound of pebbles and detritus in an almost pure stand of sagebrush near Twin Falls. (Original).

FIGURE 6. Burned area of bromegrass and sagebrush near Ontario, Oregon, illustrating the protection of the mound by its denuded area. (Original).

Table I lists several typical mound temperatures. These temperatures, both inside and outside of the mounds, vary with atmospheric temperature and are never constant. From the data in the table we can recognize the correlation between these fluctuating temperatures and the movement of the brood. This movement is gradual as a rule, the brood being transferred from one chamber to another, the last position being the optimum for the maximum or minimum temperature concerned.

The temperature must not be too high for the delicate brood to withstand, neither must it be too low for proper incubation of the brood. Minor fluctuations are met with adjustments inside of the mound. As the temperature rises during the day, the workers move the brood from the deep recesses underground into the mound and often just under the surface covering. As the temperature decreases the brood is moved from the upper chambers and returned to the lower levels. That this process is gradual has already been pointed out.

THE DENUDED AREA

The cleared or "denuded" areas surrounding mounds of *P. occidentalis* are as impressive as the mounds themselves (Fig. 1). They represent "subseres," average about five feet in diameter and are more or less regularly circular in outline. They are due to the destruction, by the worker ants, of vegetation closely surrounding the mounds. The plants are literally "chewed-down," bit by bit, from the apex to the base. The debris is either carried away by the ants or scattered by the wind. The rate and extent of denudation is proportional to the size and strength of the colony. I carefully observed *occidentalis* workers cutting down a large plant of wild lettuce at the base of a mound. Fourteen days of cutting were required for the plant, 12.1 centimeters high, to be reduced to a mere stump of 0.2 centimeters, only a few ants working at a time. Small grasses are often hewn by the sharp mandibles of a single ant. The remaining stubble eventually dries out and is disseminated by the wind. The apparent tolerance of the ants toward some plants growing in the denuded areas cannot be explained. Peppergrass (*Lepidium sp.*) seems to be commonly tolerated in many sections.

As a rule the denuded areas are cleared of all vegetation, but occasionally there are a few scattered grasses, such as

Agropyron and Stipa, growing near the periphery of the circle. Rarely do we find plants growing on the mounds themselves. Many annuals border the denuded areas, among the most common being Russian thistle (*Salsola pestifer* A. Nels.), mustards (*Sophia parviflora* (Lam.) Standl. and *Sisymbrium altissimum* L.) and bromegrass (*Bromus tectorum* L.).

One is not certain whether the denuded area is detrimental or advantageous to the life of the colony. The strong, prevailing, westerly winds of the west tend to "hollow-out" the mounds of *occidentalis* and related species which have denuded areas surrounding their mounds. This is detrimental to the

TABLE I.

Some Typical Mound Temperatures.

Temperature of*	Mound 1	Mound 2	Mound 3	Mound 4	Mound 5	Mound 6	Mound 7
Sun	97	97	**	**	**	**	**
Shade	88	88	69	69	69	69	69
Top of mound	106	91	70	70	70.5	70	70.5
Interior of base	110	93	71	70	70	71	70.2
In entrance	105	91	70	70.5	70	70	69.5

*Temperatures in Degrees F.
**Cloudy; no sunlight.

continued existence of the colony. Such is not the case with adjacent mounds of Formica which are invariably protected by surrounding vegetation, no matter how short or scant it may be. In some localities *occidentalis* mounds are tightly packed and are composed of a material which resists the average winds to a great extent. Mounds composed of loose earth, sand or detritus are much less stable than pebble mounds for they are more inclined to be destroyed or at least damaged by the sweep of wind over the denuded areas.

Of what value is the denuded area? Near Ontario, Oregon, I observed a large sagebrush-bromegrass area which had been burned-over, completely destroying the vegetation and amplifying the preponderance of *occidentalis* mounds (Fig. 6). The large denuded areas surrounding the mounds had prevented the fire from coming into direct contact with them. That there was a slight mortality of the ants is obvious, but had there been no denuded areas, the destruction of at least a large portion of the colonies would have been inevitable.

Occasionally *occidentalis* mounds do not have denuded areas. I observed full-sized mounds in large patches of annuals where the vegetation all but touched the sides. I observed two colonies in a huge area of *Bromus tectorum* L. (Bromegrass) which made no effort to clear areas around the mounds. Ants returning to the colony would continually weave to and fro, dodging stems of Bromus and often temporarily losing their loads of seed.

OBSERVATIONS IN THE TWIN FALLS, IDAHO AREA

"The Twin Falls Area, Idaho, is situated in the northern part of Twin Falls County. It lies in the southern part of

TABLE II.

ECOLOGICAL DISTRIBUTION OF OCCIDENTALIS IN THE TWIN FALLS AREA.

ANTS PRESENT			ANTS ABSENT		
Vegetation			No Vegetation		Vegetation
Abundant	Intermediate	Scarce	Wet	Dry	
Sagebrush Brome grass	Greasewood	Shadscale	Lake Margins	Sand dunes Old lake beds Plowed areas	Cultivated fields

the great inter-mountain valley known as the Snake River Plains." (1) Thus it forms a part of the Upper Sonoran Zone with its characteristic fauna and flora. The Twin Falls area covers approximately 350 square miles, or 223,360 acres.

"The climate of the area, like that of the greater part of the Snake River Plains, is characterized by a low annual rainfall, a dry atmosphere, hot summers, cold winters, and a large proportion of sunny days." (1) The average annual precipitation at Twin Falls is about 11.03 inches and the average annual snowfall 27.5 inches at the same locality.

In the Twin Falls area mounds of *occidentalis* are present only where there is vegetation. They are very abundant in greasewood communities, and occasional in regions of shadscale. However, we do not find them in all vegetational areas.

In cultivated fields, where the soil is periodically disturbed, they are not present. Nor are they abundant in very wet tracts bordering streams where there is likely to be a luxuriant growth of plants. Colonies do not exist on active sand dunes nor on the old dry lake-beds. Plowed areas only support mounds when they are undisturbed for some time and until plants begin to grow. Table II summarizes these various points.

Occidentalis brood will not mature in soils of high mositure content. Excessive moisture germinates the seeds stored by the workers, making them utterly useless for food. After a shower, under normal circumstances, when the seeds become

TABLE III.*

Distribution in Relation to the Vegetation in the Twin Falls Area.

Plant Community	Locality	Number Mounds in One-tenth Square Mile		
		Established	Incipient	Abandoned
Sage-rabbitbrush	Twin Falls	6	5	0
Sage-brome grass	Twin Falls	8	4	0
Sagebrush	Twin Falls	7	2	0
Sage-greasewood	Hagerman	6	4	0
Greasewood	Hagerman	4	5	0
Greasewood-Shad	Hammett	3	4	0
Shadscale	Hammett	0	2	0
Brome grass	Twin Falls	11	9	1

*The figures given are the means of three counts.

damp, the workers transport them to the surface of the mound where they are able to thoroughly dry. They are then returned to the seed chambers. In an area of very high humidity, if the seeds are taken to the surface to dry, they germinate instead. This is detrimental and may lead to the extinction of the colony. The result is the same when rain falls on the exposed seeds before the workers are able to carry them into the interior of the mound. Thus we occasionally observed sparse growths of annuals on the mounds themselves. The rarity of this occurrence has been pointed out in a preceding paragraph.

The relative distribution of *occidentalis* in regards to the vegetation is illustrated in Table III. Sagebrush and brome-grass areas support the greater number of colonies and shadscale communities the least. The abundance of mounds in the

bromegrass areas is explained by the harvesting habits of the ants, *Bromus tectorum* seeds being the chief seeds harvested.

Mounds of *occidentalis* are found on all types of soil in the Twin Falls area but occur most abundantly on gravelly soils. Perhaps this is due to the apparent preference for pebble mounds in many localities. Portneuf silt loam of wind-blown origin covers about 83% of the Twin Falls area (1). Table IV lists the types of soils present and the abundance of *occidentalis* mounds in these various soil areas.

TABLE IV.*

DISTRIBUTION OF MOUNDS ON VARIOUS SOILS IN THE TWIN FALLS AREA.

SOIL	LOCALITY	NUMBER MOUNDS TO ONE-TENTH SQUARE MILE
Portneuf silt loam	Twin Falls	22
Rough stony land	Twin Falls	24
Portneuf silt loam (Shallow phase)	Buhl	18
Portneuf silt loam	Castleford	22
Downey loam	Clear Lakes	7
Rough stony land	Rock Creek	26
Downey loam	Rock Creek	12
Rough stony land	Shoshone Falls	28

*See literature cited, (1).

HARVESTING HABITS

That *occidentalis* is graniverous is evidenced by the presence of seeds in many of the nest chambers. According to Wheeler (3, p. 282) *occidentalis* is one of the most characteristic of the American harvesting ants. Table V illustrates the many species of seeds found in various mounds. Seeds of *Bromus tectorum* were predominant, due to the wide expanse of this plant in Idaho.

May seeds which are present in the nest chambers do not abound in the surrounding area and are often at a considerable distance from the colony. From one mound I excavated several wheat seeds, while the nearest wheat field was two miles distant. It is possible, but not probable, that a few isolated wheat plants were growing in a nearby meadow and that these were harvested by the ants. From observations it is evident that seeds of sunflowers, thistles and other annuals have been transported great distances by the ants. In one

case the nearest sunflowers were 0.7 mile from a group of mounds, Canada Thistle, 0.4 mile, Alfalfa 1.35 miles, and Jim Hill mustard 0.25 mile. Long lines of workers were transporting the above seeds to their formicaries. The seed chambers of mounds in dense bromegrass areas often contain a greater quantity of other seeds and only a few colonies were located

TABLE V.

SEEDS HARVESTED IN THE TWIN FALLS AREA.

SEED	ABUNDANCE
Carduus arvensis L. Robs	Abundant
Carduus lanceolatus L	Abundant
Bromus tectorum L	Very abundant
Agropyron repens (L.) Beauv	Abundant
Agropyron spicatum Scribn. & Sm	Moderately abundant
Lupine sp	Scarce
Salsola pestifer A. Nels	Very abundant
Sisymbrium altissimum L	Moderately abundant
Sophia parviflora (Lam.) Standl	Moderately abundant
Sophia longipedicellata (Fourn.) Howell	Scarce
Melilotus alba Desv	Moderately abundant
Medicago lupulina L	Scarce
Ambrosia trifida L	Scarce
Ambrosia artemisiaefolia L	Scarce
Bursa bursa-pastoris L	Scarce
Thlaspi avense L	Scarce
Lychvis alba Mill	Scarce
Amaranthus retroflexus L	Scarce
Chenopodium album L	Moderately abundant
Polygonium persicaria L	Scarce
Rumex acetosella L	Scarce
Avena fatua L	Moderately abundant
Hordeum jubatum L	Abundant
Lactuca scariola L	Scarce
Chaetochloa viridis L. Nash	Scarce
Sonchus arvensis L	Scarce
Iva axillaris Pursh	Scarce
Atriplex rosea L	Abundant
Helianthus annuus L	Moderately abundant

which seemed to harvest bromegrass seeds exclusively. It is safe to state, however, that seeds of bromegrass are more generally harvested than others especially in the Twin Falls area. This is due primarily to the predominence of *Bromus tectorum* in the semi-desert areas.

COMPOUND NESTS

One of the most interesting associations of *P. occidentalis* is its relationship to other ants, either intermingled with the

colony or existing in separate nests on or in the mounds or on the denuded areas. I observed several mounds in western Wyoming which supported small crater-mounds of *Dorymyrmex pyramicus* on the faces and on the surrounding denuded areas as well. (Fig. 1). Wheeler (3, p. 426) lists the genera Dorymyrmex and Forelius as compoundly associated with *occidentalis*. McCook (2, p. 155) lists *Formica sanguinea*, *Dorymyrmex insanus* (*pyramicus*) Buckley and *Dorymyrmes flavus* McCook.

In the Painted Desert of Arizona I observed several mounds of *occidentalis* which supported small craters of *Lasius niger* var. in their denuded areas. There is no apparent relationship between the two species except the tolerance for one another. There were apparently no connecting galleries and the individuals of the Lasius colonies were not found walking on the mounds. Such compound nests are apparently rare in Idaho.

McCook (2, p. 152) mentions *Termes flavipes* as associated with *occidentalis*. I, too, have noticed this relationship, and in a large area of greasewood I found fourteen nests which contained the termites and three which did not. Their position in the nest is shown in Fig. 4.

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The Human Mechanism.

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The Human Mechanism, by HOUGH and SEDGWICK. Second Revised Edition, by J. A. WADDELL, M. D., xi, 681 pp. New York, Ginn and Co., 1931.

SEX IN ARISAEMA TRIPHYLLUM*

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Our common wild Jack-in-the-Pulpit (*Arisaema triphyllum* (L.) Torr.) is often referred to as a dioecious species. Gow (3), Atkinson (1), Pickett (5) and Schaffner (6), have noted, however, that a considerable number of the plants bear flowers of both sexes. While studying the Japanese Arisamea (*A. japonica*) which is morphologically close to our *A. triphyllum*, Maekawa (4) noted that the "Lighter corms are male and heavy corms are female without fail and the sexual state moves on from the asexual state to the male state and lastly reaches the female state and stays therein."

Schaffner (6, 7) and others have also shown that the sex of mature plants may be controlled by regulating the physiology of the plant, and Pickett (5) and Schaffner (6) have noted the difference in sex ratios in different habitats.

The present study has been conducted to ascertain the relation between the relative age and development of the plant and the type of flower appearing in the inflorescence.

The mature plant generally consists of one or two compound leaves and an elongated flower stalk, the aerial parts arising from a subterranean perennial corm. The flowers are borne on a spadix and are surrounded by a spathe, which is typical of all the Araceae.

Small, single-leaved, non-flowering plants commonly occur associated with the mature plants. These small plants have generally arisen from lateral buds on the parent corm. The plants originating from these "bud corms" soon become separated from the parent plant and after several years of development produce flowers. Occasional isolated individuals, or even small clumps of equal-aged plants, may be noted in areas where other plants are not abundant. It seems probable in these cases that the plant has arisen from a seed, or in the case of a clump of equal-aged plants, from the seeds of a single

*Papers from the Department of Botany, the Ohio State University, No. 293.

spadix. It is to be noted, however, that vegetative multiplication is much more common than reproduction by means of seeds.

Studies by the writer since 1925, both on marked plants in the field and in experimental plots, have shown that *Arisaema triphyllum* begins as a weak, non-flowering plant with a small corm. This is true for both the seedling plant and the plant having its origin in a vegetative off-shoot.

After several years of growth—generally more than three, depending on the habitat—the plant has its first flowers. The first inflorescence is generally small and contains only staminate or male flowers.

Since the habitat is a decided factor in the development of the individual, subsequent stages in the life history are closely linked with the environment. If the plant is in a moist, rich woods and little disturbed by animals, it increases in size from year to year, both in the aerial and subterranean parts.

In several years a few carpellate or female flowers may appear on the spadix, sometimes mixed with the staminate flowers, but generally near the base of the inflorescence. This intermediate or monoecious stage generally lasts several years, the proportion of carpellate flowers becoming greater until the whole inflorescence is made up of carpellate flowers.

It is thus apparent that in *Arisaema triphyllum* a single plant, if grown in a suitable habitat will, during its life history, run the whole gaunt of sexual expression from the immature non-flowering condition into the male and from that through varying degrees of intersexuality into a female condition. It remains thus as long as the plant is undisturbed, or does not become weakened through an over-production of side corms.

The stability of the sexual state is dependent upon the physiological condition of the individual. If the habitat is unfavorable to good growth, the plant may remain in the staminate or monoecious state indefinitely.

Schaffner (7) Maekawa (4) and others have shown that removal of the lower or storage part of the corm or a portion of the leaf surface throws the plant, in the succeeding year, into a condition similar to that occurring earlier in the life history. Specifically, if a small portion of the corm or of the leaf is removed from a mature plant bearing carpellate flowers, the plant will produce a mixed inflorescence the next year. If, however, the pruning is severe the plant may be thrown

into the staminate, or even the non-flowering condition. It is of course necessary to do this before the time of flower bud formation.

It is therefore reasonable to suppose that the basic physiology of the plant, influenced by the activity of the synthetic portion or the storage regions, directly influences the production of the different sexual types.

While no extended physiological studies have been made by the writer, certain correlations have been shown to exist between the physiology of the individual and its sexual expression.

The writer (2) has previously noted in twelve species of plants, including *Arisaema triphyllum*, that a portion of a plant bearing staminate structures has a higher catalase activity than similar structures bearing carpellate flowers. It is not intended to imply that the enzym catalase is a regulator, but rather a valuable indicator of the metabolic level of the portion of the organism studied.

A study of the activity of this enzym is relatively simple, consisting merely of measuring the amount of oxygen released from a standard quantity of hydrogen peroxide by the enzym in a given quantity of plant material. A more extended discussion of the method used has already been presented by the writer (2).

In the present study, determinations of the activity of the enzym in the expressed juice of the corms of plants bearing the various types of inflorescences were made. The plants were collected in a moist, beech woods near Westerville, Ohio, May 20, and taken into the laboratory where the determinations were made as soon as possible.

The following table (Table I) shows the results obtained from determinations on a total of 22 corms fairly evenly divided between the different types.

TABLE I.

Arisaema triphyllum.

Average for the Catalase Activity of the Expressed Juice of the Corms. Readings in cc. of Gas Produced in 5 Min. at 21° C.

Non-flowering	Staminate	Monoecious	Carpellate
4.3	7.2	6.4	4.8

It is thus apparent that the corms of the pure staminate plants had a higher catalase activity than those of the pure carpellate plants, while those giving rise to the monoecious or mixed inflorescences had an intermediate position. The non-flowering plants were the least active.

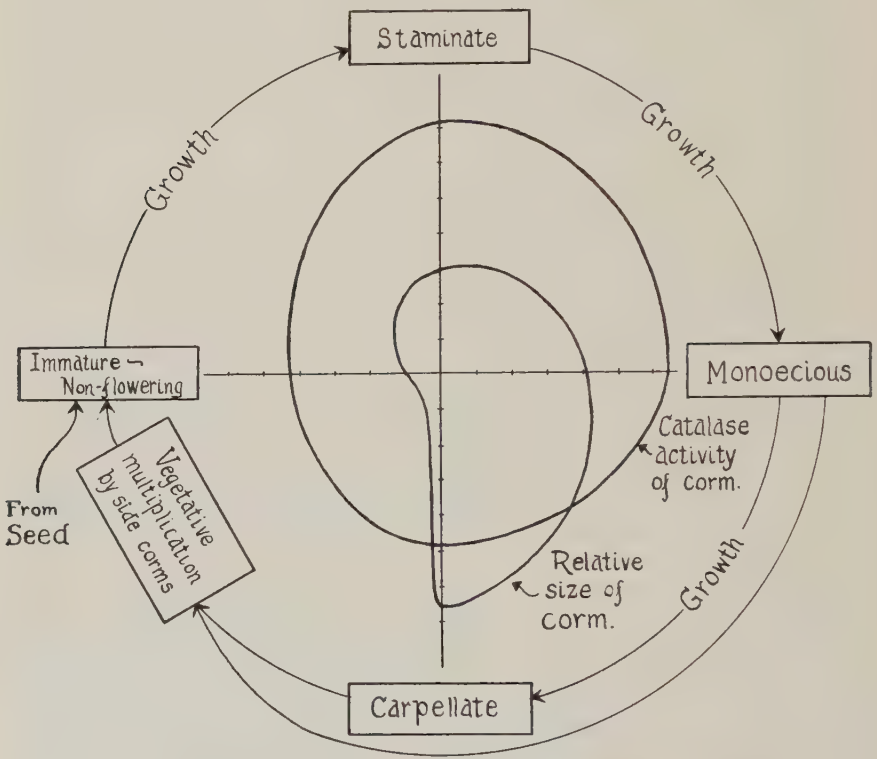

FIGURE 1. Diagram of the normal life history of *Arisaema triphyllum*, showing the relation between size and catalase activity of the corm and the sexual expression of the inflorescence.

Figure 1 is a diagram of the life history of a plant, showing the normal sequence of sexual expression, the catalase activity and relative weight of the corm.

CONCLUSIONS.

Arisaema triphyllum is not a true dioecious plant but undergoes a series of changes in the course of its life history. It arises either from a vegetative side corm or a seed as a small non-flowering individual. Later the plant produces successively

a pure staminate, next a mixed and last a pure carpellate or female inflorescence.

The sexual states are relatively unstable, being easily modified or changed by natural fluctuations in the environment or by mutilation of the vegetative parts of the plant.

Plants producing staminate flowers arise from corms characteristically light in weight and high in catalase activity, while those producing carpellate flowers are heavier with a lower catalase activity. Plants in a transitional or monoecious stage have an intermediate corm weight and catalase activity.

The type of sexual expression in *Arisaema triphyllum* is induced by the basic physiology of the vegetative parts of the plant at the time of flower bud formation.

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Law for the Physician.

That ignorance of the law is neither a valid nor an economic excuse is a recognized principle in our every-day contacts. To the physician, who makes many more legal contacts than the average layman, this principle assumes considerable importance. The physician is made liable to action at law by nearly every professional act.

A physician well versed in legal matters has undertaken to outline the fundamentals of medical jurisprudence for his professional colleagues. Medical jurisprudence is that branch of science which shows how the law affects the practice of medicine, as opposed to legal medicine, which applies to the manner in which medical science affects the practice of law.

The volume contains chapters on the contractual relationships of physicians, witnesses and evidence, torts, property rights, physicians and criminal responsibility, and finally a very interesting chapter on physicians as lawmakers.

The book is clearly and concisely written, illustrated with abundant cases, and is designed to be of real personal service to the physician in his contacts with other people.

Medical Jurisprudence, by C. SCHEFFEL, M. D., LL. B., XII + 313 pp., Philadelphia, P. Blakeston's Son & Co., Inc., 1931.

STUDIES IN HUMAN INHERITANCE VII
HEMOPHILIA.

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Recently Birch (1931) has reported the use of the female sex hormone in the control of hemophilia. While we can not question the results of this treatment as recorded, its use is based on a fundamental misconception, to which attention should be directed. The author says "Taking into consideration that only males have the disease, while it is transmitted through the unaffected female, one is forced to the conclusion that if the female can transmit the disease, she must potentially have the disease. Then there must be something in the female mechanism which holds the disease in abeyance." Based on this assumption, ovarian extract and ovarian transplants were used as a means of control for hemophilia in man, with apparently good results.

It must first be pointed out that it is not in the least necessary to assume that because unaffected females can transmit the disease they must potentially have the disease. Such a conclusion is contrary to all genetic principles. Hemophilia is known to be a sex-linked character. Males show it with a definite frequency because only one of the pair of sex chromosomes in the male carries the factor, thus making a single dose of the factor *h* for hemophilia effective. In women, a single dose of the factor will be recessive to the normal dominant allelomorph on the other member of this pair of chromosomes. Unaffected males also have this normal dominant factor *H*. Of the women who transmit the disease, practically all, if not absolutely all, will be heterozygous, free from the symptoms because of the presence of the normal dominant allelomorph.

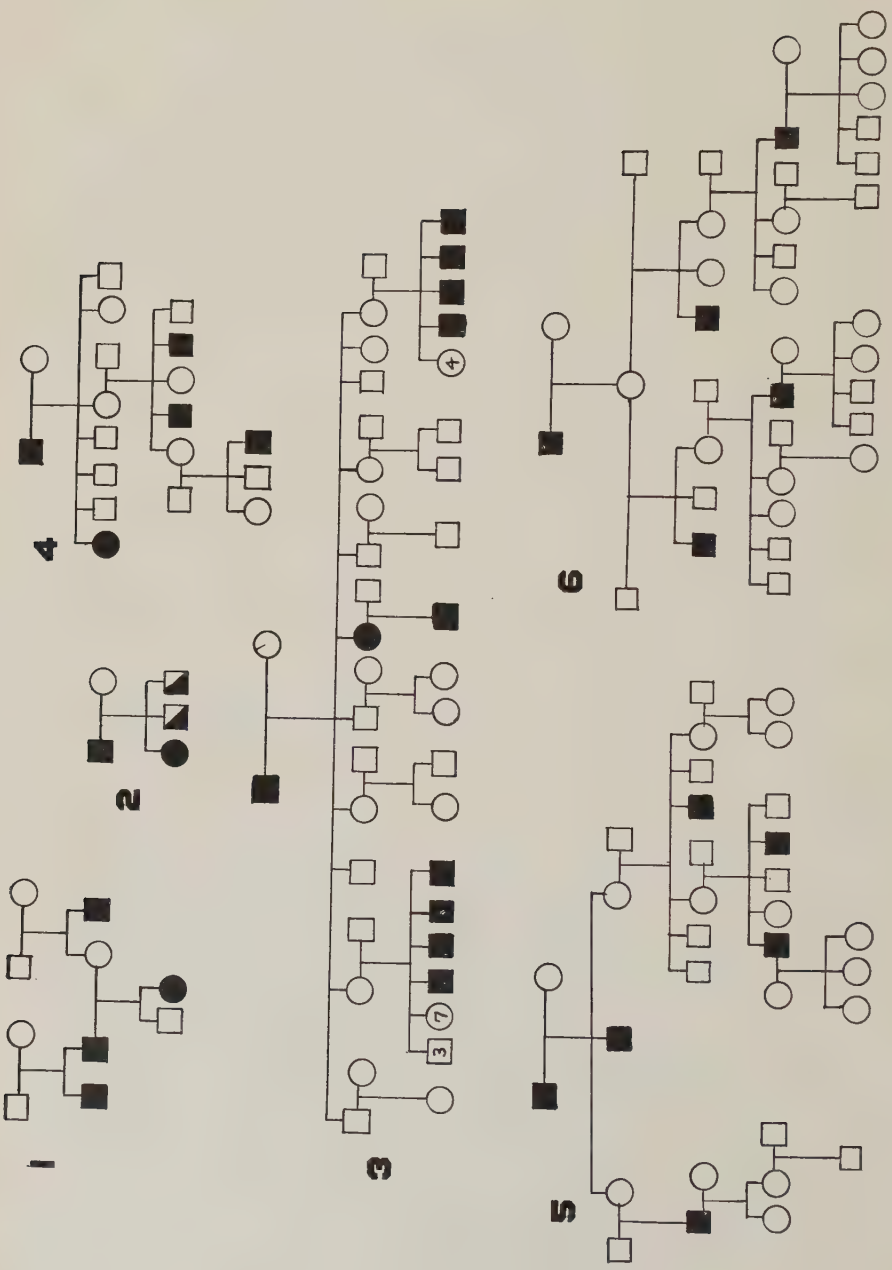
There is thus no *a priori* reason for supposing that the female sex hormone should be a specific for the control of hemophilia. It is known that injection of a foreign protein is efficacious as a control for this disease (Minot and Buckman 1927), and it would seem safer to assume that the results recorded by Birch are manifestations of a more general phenomenon, rather than to invoke a more specialized and definitely questionable hypothesis as an explanation.

The possibility exists that females receiving the double dose of the gene for hemophilia may live without manifesting symptoms of the disease. This is unlikely from a genetic standpoint, but if it were the case, Birch's hypothesis might still be tenable. This brings up again the old question as to the fate of homozygous hemophilic females. Do they exist with the symptoms of the disease? Do they exist as apparently normal individuals because of some protective mechanism? Has such a zygote ever been formed and the result recorded? Or is a double dose of the gene lethal, so that they never exist at all? Geneticists have favored the last hypothesis.

A female of the formula *hh* would only be expected to occur when a hemophilic man married a woman who was a carrier, or who was herself hemophilic. How often have matings of this sort actually occured in the pedigrees which have been recorded? In looking for such matings, it is necessary to search for instances where a hemophilic man has a hemophilic son or a hemophilic father-in-law. In such cases he might theoretically have a hemophilic daughter, since the wife would certainly be a carrier. A hemophilic brother or grandfather of the wife, even though her father were normal, would indicate that she might be a carrier.

Color-blindness, which is also a sex-linked character, presents the same requirements. To illustrate how this character can appear very occasionally in women, Fig. 1 is presented from our records.

Upon examination of 250 published pedigrees of hemophilia, the conditions under which a hemophilic woman would be expected to arise are found to be extremely rare. This is to be expected, as only 11% of hemophilic males live to be 22, and the chances of these marrying carrier females are extremely small. Only nine times in these 250 pedigrees, involving many hundreds of hemophilia males, did an alleged hemophilic man marry a known carrier. Seven of these cases are authoritatively considered by Bulloch and Fildes, who reviewed them, to be not true hemophilia at all. These are the Fischer, Weitz, Heath, Dunn III, Vanderveer, Treves and Masters families. In another instance (the Mampel family, reported in 1908 by Morawitz and Lossen), Klug (1926) has shown that several of the alleged hemophilic males did not have hemophilia, but merely said they did in order to escape military service. These included one who married a carrier. Thus this case must also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be left out of consideration. This leaves but a single published instance (the Hauser-Keller family, from Stahel, 1880) in which a known hemophilic male married a known carrier female. One hemophilic son and one normal daughter were produced, thus giving no evidence as to the possibility of hemophilic daughters.

In the 75 families recorded by Bulloch and Fildes as instances of true hemophilia, involving several hundred hemophilic men, there are found nineteen cases of alleged hemophilia in women. Of these, 15 had normal fathers, and therefore from a genetic standpoint could not have had hemophilia. The other four had hemophilic fathers, but each had at least one normal son, which could not happen if they were homozygous *hh* females. We can thus agree from a genetic viewpoint that these were not cases of hemophilia in women.

Three interesting recent pedigrees are on record in which hemophilic females are reported. In each of these cases the father is hemophilic, but there is no proof that the mother is a carrier, although she may very well be.

In the Nar family (Figure 2, after Davenport, 1930) a hemophilic man had a daughter who was diagnosed as hemophilic. She had a coagulation time of 15 minutes. She has two brothers, aged 2 and 4, who although too young to be definitely diagnosed, bleed very easily and for a long time after minor cuts, and are probably hemophilic, indicating that the mother is a true carrier.

Warde (1923) gives a pedigree involving a hemophilic woman. Her father was hemophilic, as was her only son. She suffered extremely from hemorrhage at the birth of her son,

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EXPLANATION OF FIGURES

FIGURE 1. The occurrence of color-blindness, a sex-linked character, in women. The H. family, Ohio. Similar conditions would be necessary for the appearance of hemophilia in women.

FIGURE 2. The Nar family, after Davenport. The daughter, aged 8, has been diagnosed as hemophilic. The two sons are too young to be definitely diagnosed, but bleed very easily and for a long time after cuts.

FIGURE 3. Warde's pedigree involving a hemophilic woman.

FIGURE 4. The Dorr family, after Madlener, showing alleged hemophilia in a woman.

FIGURE 5. Mc C. family, Ohio, showing conditions (second generation) under which a hemophilic female might be expected to arise. This pedigree is the second one to be published in which such conditions occur. In this case both daughters were free from the disease, but carriers.

FIGURE 6. Co. family, Ohio, showing the identical transmission of hemophilia through both lines of descent from a carrier who married twice.

as well as from other operations and minor cuts. This family is shown in Figure 3.

An interesting pedigree is given by Madlener (1928). The girl involved had subcutaneous hemorrhage from an early age, and frequently bled all day from a scratch. It has been suggested by Lenz that perhaps she was an intersex. This family is shown in Figure 4.

It is of course possible that even the cases just cited are examples of purpura or some other hemorrhagic defect, and not true hemophilia. They may be due to imperfect dominance of the normal allelomorph of the hemophilia gene. Laboratory diagnoses are unfortunately all too rare in reported cases. It is of interest to note, however, that in these three cases the father was hemophilic, and in one case the son as well, thus fulfilling the genetic requirements. It is to be hoped that adequate laboratory diagnoses may be made in these cases.

There still remains the bare possibility that potentially hemophilic females (*hh*) live as normal individuals, protected by some mechanism peculiar to the female sex. Such women, if they exist, should have all hemophilic sons, no normal ones. The fact that only one published family is found where a female of the formula *hh* would be likely to arise, makes conclusive data on this point impossible to obtain. There is no logical basis, however, for supporting such a supposition.

Among our records at the genetics laboratory of the Ohio State University are several cases worthy of note. First is a case where a hemophilic male married a carrier female, as evidenced by a hemophilic son. This is apparently only the second authentic case to be recorded. The diagnosis in this family was supported by complete laboratory examination. In the second generation of this pedigree half of the daughters might be expected to have hemophilia. The two daughters occurring here were normal, however, although both were carriers. Here again is no definite evidence for or against the possibility of the realization of a hemophilic female. This family is shown in Figure 5.

Three families in Ohio have been referred to us as containing hemophilic females. Upon laboratory diagnosis, no evidence of true hemophilia was found.

Another new pedigree of hemophilia is offered here, chosen from many in our records as showing the practically identical course of heredity through both lines of descent from a known carrier who married twice. (Figure 6).

CONCLUSIONS.

Upon the examination of 250 published pedigrees of hemophilia, only one authentic instance could be found where a known hemophilic male had married a known carrier female, and where a hemophilic daughter might therefore be expected. A second pedigree involving a mating of this sort is presented in this paper. A total of three daughters, all normal, and two hemophilic sons, result from these two matings. Examination of 22 pedigrees where hemophilic women are recorded indicates that from a genetic standpoint nineteen of them could not have had hemophilia. The other three cases, more recently described, may possibly be true hemophilia. There is therefore at hand insufficient data with which to definitely settle the question as to the fate of homozygous females. There is not the slightest evidence, however, that such women can live as normal individuals because of some protective mechanism.

Women who transmit the disease are undoubtedly all heterozygous, free from the symptoms of the disease not because of any inherent protective mechanism peculiar to their sex, but because of the presence of the dominant allelomorph of the hereditary gene for hemophilia, which is also present in non-hemophilic males. There is thus no basis for Birch's assumption that women who transmit the disease must potentially have the disease. The suggestion made at the beginning of this paper is therefore offered again, that the results achieved by Birch are manifestations of the broader phenomenon that injection of a foreign protein is efficacious as a control for hemophilia. Experiments are now in progress in our laboratory in connection with the University Hospital, to test the value of this suggestion. This paper is merely to call attention to the genetic aspects of the problem.

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Minot, G. R. and **Buckman, T. E.** 1927. "Hemophilia," in Cecil, "Textbook of Medicine," p. 961, Phila., W. B. Saunders Co.
Morawitz, P. and **Lossen, J.** 1908. Deutsche Arch. f. klin. Med. 94: 110. (Pedigree 389 in Bulloch and Fildes.)
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Warde, M. 1923. Brit. Med. J., 1923: 599.

ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1931.*

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As has been the case for a number of years past, a considerable number of new records have again been added to the Ohio state plant list. Some of these species are very conspicuous plants and it is surprising that no botanist has reported their presence in the state before. Mr. Floyd Bartley and Mr. Leslie L. Pontius deserve special credit for a number of these interesting discoveries, some of which advance the geographic boundaries of several species several hundred miles beyond their supposed limits. Since a new State Catalog is being published, the present list will be the final additions to the old 1914 Catalog of Ohio Vascular Plants. The new catalog will bring our knowledge of distribution up to date and make further study of our flora much more convenient than it has been in recent years.

25a. *Asplenium cryptolepis ohionis* Fern. Mineral Springs region, Adams Co. Margaret A. McCloud.

40. *Dennstaedtia punctilobula* (Mx.) Moore. Boulder-fern. "Red Hills," near Central College, Franklin Co. F. B. Chapman.

63. *Lycopodium complanatum* L. Trailing Club-moss. Corning, Perry Co. Rodney D. Book.

69. *Pinus rigida* Mill. Pitch Pine. Linton Twp., Coshocton Co. L. A. Robertson.

70. *Pinus virginiana* Mill. Scrub Pine. Byesville, Guernsey Co. L. A. Robertson.

75.1. *Juniperus horizontalis* Moench. Shrubby Juniper. Along a fence, apparently escaped from cultivation. Cooney, Williams Co. John H. Schaffner.

135. *Cyperus schweinitzii* Torr. Schweinitz's Cyperus. Beach at Ashtabula, Ashtabula Co. L. E. Hicks.

172.1. *Eriophorum gracile* Koch. Slender Cotton-sedge. In bog at Baumgardner's Pond., Jackson Twp., Franklin Co. R. B. Gordon and E. S. Thomas.

226. *Carex varia* Muhl. Emmon's Sedge. Elyria, Lorain Co. (E. S. Steele). Received from F. O. Grover.

295.1. *Arundinaria tecta* (Walt.) Muhl. Cane. Mineral Springs region, Adams Co. "Escaped from cultivation." E. Lucy Braun and R. B. Gordon.

340. *Sphenophyllus capillaris* (L.) Britt. Hair-like Sphenophyllus. Kettle Hill, south of Lancaster, Fairfield Co. R. B. Gordon, Bruce Hill, and Wm. Ireland.

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*Papers from the Department of Botany, The Ohio State University, No. 297.

348. *Cynosurus cristatus* L. Dogtail-grass. Oberlin, Lorain Co. F. O. Grover.
368. *Elymus hirsutiglumis* Scribn. & Sm. Strict Wild-rye. Elyria, Lorain Co. (W. M. Dick). Received from F. O. Grover.
378. *Capriola dactylon* (L.) Ktz. Bermuda-grass. Cheshire, Gallia Co. Geo. W. McAllister. Hamilton, Butler Co. J. W. Timberman.
380. *Atheropogon curtipendulus* (Mx.) Fourn. Tall Gramma-grass. Clifton Gorge, Clark Co. Floyd Bartley and Leslie L. Pontius.
383. *Sporobolus asper* (Mx.) Kunth. Longleaf Rush-grass. Union Twp., Logan Co. E. N. Transeau.
389. *Calamagrostis cinnoides* (Muhl.) Scribn. Nuttall's Reed-grass. Granville, Licking Co. (H. L. Jones). Received from F. O. Grover.
416. *Phalaris canariensis* L. Canary-grass. Twinsburg, Summit Co. E. M. Herrick.
423. *Panicum miliaceum* L. Millet Panic-grass. New Vienna, Clinton Co. Katie M. Roads.
450. *Leptoloma cognatum* (Schultes) Chase. Fall Witch-grass. Kettle Hill, south of Lancaster, Fairfield Co. R. B. Gordon.
469.1. *Andropogon elliottii* Chapm. Elliott's Beard-grass. McArthur, Vinton Co. Floyd Bartley and Leslie L. Pontius. Nile Twp., Scioto Co. Conrad Roth.
470. *Andropogon virginicus* L. Virginia Beard-grass. Beach City, Sugar Creek Twp., Stark Co. W. H. Camp.
484.1. *Allium sibiricum* L. Chives. Hartsgrove, Ashtabula Co. L. E. Hicks.
547. *Juncus brachycephalus* (Engelm.) Buch. Small-headed Rush. Conneaut, Ashtabula Co. L. E. Hicks.
559. *Gemmingia chinensis* (L.) Ktz. Blackberry-lily. Wapakoneta, Auglaize Co. Wm. Kayser.
589. *Ibidium ovale* (Lindl.) House. Small-flowered Lady's-tresses. Lynx, Adams Co. Reeve Bailey and C. F. Walker.
591. *Ibidium beckii* (Lindl.) House. Little Lady's-tresses. Nile Twp., Scioto Co. Conrad Roth, C. F. Walker. Washington Twp., Jackson Co. C. F. Walker and E. S. Thomas. Colerain Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.
595. *Liparis liliifolia* (L.) Rich. Large Twayblade. Red Hills near Central College, Franklin Co. F. B. Chapman and Wm. Ireland, Jr.
599. *Corallorrhiza corallorrhiza* (L.) Karst. Early Coral-root. Sugar Grove, Fairfield Co. Glenn W. Blaydes.
603.1. *Magnolia macrophylla* Mx. Large-leaf Magnolia. At Rock Branch and Barleytown, Jackson Co. Leslie L. Pontius and Floyd Bartley.
629. *Aquilegia vulgaris* L. European Columbine. "Common escape." Andover Twp., Ashtabula Co. L. E. Hicks.
682. *Berteroa incana* (L.) DC. Hoary Berteroa. Carpenter, Meigs Co. "In alfalfa field." C. J. Willard.
688. *Camelina microcarpa* Andrz. Common False-flax. Wooster, Wayne Co. L. E. Hicks.
701.1. *Lepidium perfoliatum* L. Perfoliate Peppergrass. Bellefontaine, Logan Co. O. D. Diller. New Bremen, Auglaize Co. G. W. Owen. Barnesville, Belmont Co. Emma E. Laughlin.
740. *Dentaria maxima* Nutt. Large Toothwort. Conneaut, Ashtabula Co. L. E. Hicks.
742.1. *Dentaria multifida* Muhl. Multifid Toothwort. Delaware, Delaware Co. C. E. O'Neal.
747.1. *Brassica napo-brassica* Mill. Rutabaga. From Europe. Persistent after cultivation. New Lyme, Ashtabula Co. L. E. Hicks.
751. *Raphanus raphanistrum* L. Wild Radish. Hillsboro, Highland Co. Katie M. Roads.
809. *Chamaesyce rafinesqui* (Greene) Small. Hairy Spurge. Barnesville, Belmont Co. Emma E. Laughlin.
812. *Chamaesyce polygonifolia* (L.) Small. Knotweed Spurge. Beach at Ashtabula, Ashtabula Co. L. E. Hicks.
820. *Malva alcea* L. European Mallow. "Roadside." Brownhelm, Lorain Co. (A. A. Wright). Received from F. O. Grover.

829.1. *Hibiscus oculiroseus* Britt. Crimson-eye Rose-mallow. Stage's Pond, three miles south of Ashville, Pickaway Co. C. F. Walker, L. M. Shupe.

875. *Viola affinis* Le C. Thinleaf Blue Violet. Red Hills east of Big Walnut Creek, Central College, Franklin Co. R. B. Gordon and F. B. Chapman.

898. *Alsine graminea* (L.) Britt. Lesser Stitchwort. Beach at Ashtabula, Ashtabula Co. L. E. Hicks.

920. *Silene caroliniana* Walt. Carolina Catchfly. East Liberty, Summit Co. L. E. Hicks.

925. *Silene armeria* L. Sweet William Catchfly. Conneaut River, Ashtabula Co. L. E. Hicks.

998. *Polygonum tenue* Mx. Slender Knotweed. Liberty Twp., Ross Co. Floyd Bartley and Leslie L. Pontius. Kettle Hill, south of Lancaster, Fairfield Co. R. B. Gordon.

1000. *Geum rivale* L. Purple Avens. Andover Twp., Ashtabula Co. L. E. Hicks.

1002. *Geum flavum* (Port.) Bickn. Cream-colored Avens. Windsor Mills, Ashtabula Co. L. E. Hicks.

1069. *Crataegus brainerdi* Sarg. Brainerd's Hawthorn. Wapakoneta, Auglaize Co. Wm. Kayser.

1070. *Crataegus chrysocarpa* Ashe. Roundleaf Hawthorn. Wapakoneta, Auglaize Co. Wm. Kayser.

1167. *Vicia angustifolia* L. Narrow-leaf Vetch. Wapakoneta, Auglaize Co. Wm. Kayser.

1189. *Sullivantia sullivantii* (T. & G.) Britt. Sullivantia. West of Portsmouth, Scioto Co. Glenn W. Blaydes.

1248.1. *Celtis pumila* (Muhl.) Pursh. Dwarf Hackberry. Lynx, Adams Co. Conrad Roth. "Limestone cliff." Brush Creek Twp., Highland Co. Floyd Bartley and Leslie L. Pontius.

1219.1. *Pachystima canbyi* Gr. Mountain-lover. Brush Creek Twp., Highland Co. Floyd Bartley and Leslie L. Pontius.

1400.1. *Xolisma ligustrina* (L.) Britt. Xolisma. "Growing in a swamp." Liberty Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.

1404. *Uva-ursi uva-ursi* (L.) Britt. Bearberry. Beach at Ashtabula, Ashtabula Co. L. E. Hicks.

1424. *Gilia rubra* (L.) Heller. Standing-cypress. Woodville, Sandusky Co. E. L. Moseley.

1464. *Gentiana quinquefolia* L. Stiff Gentian. Banks of Deer Creek, Williamsport, Pickaway Co. L. M. Shupe. South Branch of Captina Creek, Somerton, Belmont Co. Emma E. Laughlin.

1465. *Gentiana crinita* Froel. Fringed Gentian. Hocking Twp., Fairfield Co. and Williamsport, Pickaway Co. L. M. Shupe. Union Twp., Logan Co. E. N. Transeau.

1490. *Asclepias variegata* L. White Milkweed. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

1494. *Gonolobus laevis* Mx. Sandvine. Pickerington, Fairfield Co. DeWitt C. Miller.

1573. *Orobanche ludoviciana* Nutt. Louisiana Broom-rape. On *Ambrosia trifida*, banks of Ohio River, Neville, Clermont Co. John H. Schaffner. On cultivated tobacco, same locality. H. M. Taylor and A. L. Pierstorff.

1580. *Martynia louisiana* Mill. Unicorn-plant. "A common weed in a large cucumber patch." Hillsboro, Highland Co. Katie M. Roads.

1732. *Conium maculatum* L. Poison-hemlock. Condit, Delaware Co. L. E. Hicks.

1747. *Cornus rugosa* Lam. Roundleaf Dogwood. Conneaut River, Ashtabula Co. L. E. Hicks.

1778.1. *Viburnum venosum* Britt. Veiny Arrow-wood. Coal Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

1793. *Lonicera xylosteum* L. European Fly Honeysuckle. Kingsville, Ashtabula Co. L. E. Hicks.

1817. *Lobelia puberula* Mx. Downy Lobelia. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

1834.1. *Rudbeckia umbrosa* Boynt. & Bead. Woodland Cone-flower. "In damp woods." Brush Creek Twp., Highland Co. Leslie L. Pontius and Floyd Bartley.
1850. *Helianthus tracheliifolius* Mill. Throatwort Sunflower. Conneaut, Ashtabula Co. L. E. Hicks.
1883. *Parthenium hysterophorus* L. Parthenium. Hamilton, Butler Co. D. T. Herrman.
1903. *Chrysopsis mariana* (L.) Ell. Maryland Golden-aster. McArthur, Vinton Co. Leslie L. Pontius and Floyd Bartley.
1904. *Solidago squarrosa* Muhl. Stout Goldenrod. Washington Twp., Scioto Co. Conrad Roth.
1927. *Bellis perennis* L. European Daisy. "In lawn." Columbus, Franklin Co. E. S. Thomas.
1931.1. *Aster schreberi* Nees. Schreber's Aster. Conneaut, Ashtabula Co. L. E. Hicks. Brush Creek Twp., Highland Co. Floyd Bartley and Leslie L. Pontius. Oberlin, Lorain Co. F. O. Grover.
1941. *Aster patens* Ait. Late Purple Aster. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.
1947.1. *Aster concinnus* Willd. Narrowleaf Smooth Aster. Brush Creek Twp., Highland Co. "Limestone cliff." Floyd Bartley and Leslie L. Pontius.
1953. *Aster dumosus* L. Bushy Aster. Catawba Island, Ottawa Co. R. B. Gordon.
1967. *Ionactis linariifolius* (L.) Greene. Stiffleaf Aster. Liberty Twp., Jackson Co. Also in Coal Twp. Floyd Bartley and Leslie L. Pontius.
1983. *Lacinaria spicata* (L.) Ktz. Dense Blazing-star. Hocking Twp., Fairfield Co. L. M. Shupe.
1991. *Anthemis arvensis* L. Field Dog-fennel. Hillsboro, Highland Co. Katie M. Roads.
2004. *Artemisia vulgaris* L. Common Mugwort. Buchtel, Athens Co. Len. Stephenson.
2005. *Artemisia pontica* L. Roman Wormwood. Rock Creek, Ashtabula Co. L. E. Hicks.
2019.2. *Carduus crispus* L. Curled Plumeless Thistle. "Growing in pasture field." Pickaway Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
2028.1. *Centauria maculosa* Lam. Spotted Star-thistle. Rock Mill, Fayette Co. "Abundant in a pasture field." Floyd Bartley and Leslie L. Pontius.
2035.3. *Apargia autumnale* (L.) Hoffm. Fall Hawkbit. Trumbull, Ashtabula Co. L. E. Hicks.
2039. *Sonchus arvensis* L. Field Sow-thistle. Beach at Ashtabula, Ashtabula Co. L. E. Hicks.
2051.1. *Nabalus trifoliolatus* Cass. Tall Rattlesnake-root. Conneaut Harbor, Ashtabula Co. L. E. Hicks.
2061.1. *Hieracium florentinum* All. King-devil. Conneaut, Ashtabula Co. From Europe. L. E. Hicks.
2062.1. *Hieracium pratense* Tausch. Field Hawkweed. Williamsfield Twp., Ashtabula Co. L. E. Hicks.

The Queen of the Sciences.

A group of publishers, headed by the Williams and Wilkins Co., have undertaken the publication of a series of volumes presenting the essential features of those fundamental sciences which are the foundation stones of modern industry. The first volume of this "Century of Progress" series is at hand, a delightful excursion into the field of mathematics. Starting with a chapter on points of view, the author progressively analyzes mathematical truth, algebra, geometry, arithmetic, and the concept of the infinite. It is all done in a whimsical yet strictly scientific vein, and will give several hours of extremely pleasurable and profitable reading. May the volumes to follow live up to the standard set by the first one to appear.

The Queen of the Sciences, by E. T. Bell, Ph. D., 138 pp. Baltimore, the Williams and Wilkins Co., 1931. $1.00.

CORRECTION.

In the paper by Robert M. Geist, entitled "Additional Mallophaga from Ohio Birds," appearing in the OHIO JOURNAL OF SCIENCE for November, 1931, the following correction should be noted:

In the first sentence of the second paragraph of the article, the sentence, "The following list includes 45 additional species . . . ." should read, "The following list includes 21 additional species . . . . ."